THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. VII.

No. V.—MAY, 1900.

ORIGINAL ARTICLES.

I.—Studies in Edrioasteroidea. II. *Edrioaster Buchianus* Forbes sp.

By F. A. Bather, M.A., F.G.S.

ERRATUM.

Page 147 (April Number), line 14 from bottom: *for* "on both the north and south banks," *read* "in cliffs both north and south."

(Mem. Geol. Surv. Gt. Brit., III, 1st ed., 1866), criticised a little, but illuminated less; while the same Appendix in the second edition, 1881, though "greatly enlarged and partly rearranged by Robert Etheridge, F.R.S.," merely introduced verbal alterations into Salter's account.

Allusions to this fossil by writers who have not themselves examined it serve chiefly to show the need that exists for a fresh description. Through the kindness of the Director-General of the Geological Survey and of Mr. E. T. Newton, to whom my sincere thanks are here offered, the original specimens were placed at my disposal for several months. About two years ago the first draft of this paper and some of the illustrations were sent to Dr. Otto Jaekel in Berlin, and have been utilised on pp. 44–46 of his splendid volume "Stammesgeschichte der Pelmatozoen. I. Thecoidea und Cystoidea" (1899). Thanks to Mr. J. F. Whiteaves and the Director of the Canadian Geological Survey, I subsequently learned the true structure of *Edrioaster Bigsbyi*, which was unknown to Dr. Jaekel when he wrote the pages referred to. Hence some interpretations in the present account differ from those given by Dr. Jaekel. They agree, however, with the statements in chapter xii—The Edrioasteroidea—of "A Treatise on Zoology, Part III, The Echinoderma," edited by Professor E. Ray Lankester

(London, 1900). Some of the points will be better understood after publication of Study III, which will deal with *E. Bigsbyi*.

The terms used and the arrangement followed in the present account are the same as those in Study I. *Dinocystis Barroisi*.[1]

Horizon and Locality.

The specimens preserved under this name in the Museum of Practical Geology, V $\frac{3}{77}$, were obtained during the summer of 1847 from the Caradoc beds, two miles west of Ysputty Evan; that is to say, about two miles south of Pentre Voelas, and therefore in Denbighshire and not in Caernarvonshire as stated by J. W. Salter (op. cit., 1866, p. 262) and by R. Etheridge, sen. (op. cit., 1881, pp. 395 and 407). Mr. Etheridge informs me that the specimens were not found *in situ*, but were collected by Mr. Gibbs from a wall of loose stones, all of the same material. There seems, however, no reason to doubt that they came from the Caradoc beds of some quarry in the immediate vicinity, for they have the well-known characters of those beds. The matrix is an indurated sandstone, hardly to be described as "schistose" in any modern sense of the word. It contains remains of crinoid stems, brachiopods, and corals; the calcareous portions of these have been dissolved from the outer portions of the stone, and the same is the case with the edrioasteroid.

Description of the Type-Specimen.

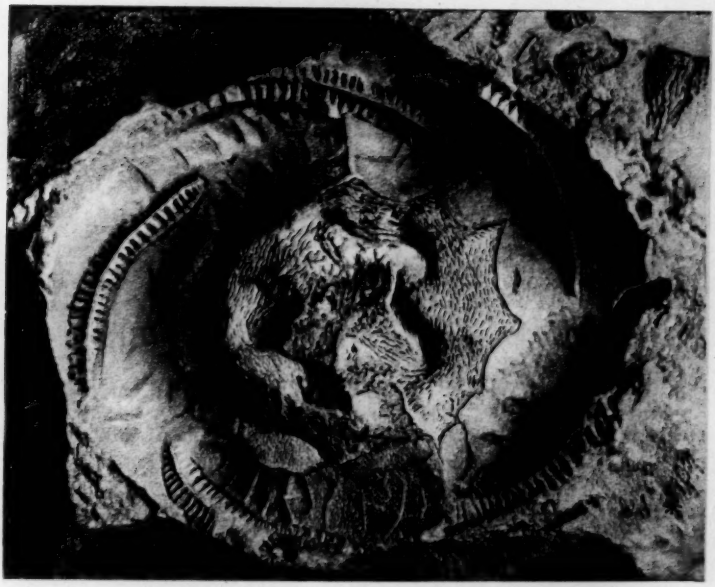
This consists of an *internal cast* of the whole individual (Pl. VIII) and an *external impression* of its abactinal surface (Pl. IX). There is also preserved, in the central region of the abactinal surface of the cast (Pl. VIII, Fig. 3), a small portion of the original theca. Except when said to be otherwise, the statements refer to the internal cast.

The periphery is subpentagonal; the sides of the pentagon correspond to the interradial areas, and are slightly convex. The length along the sagittal plane is 36 mm. The transverse diameter is 32 mm.[2] The greatest width of each side is about 20 mm.

From the periphery, the theca rises rather steeply, then curves gently over to a slight depression around the actinal pole; towards the under surface it bends more suddenly. Seen from the side (Pl. VIII, Fig. 2) the theca looks like a round cap squashed in at the top. If the fossil be placed on a flat surface, it reaches a height of 18·5 mm.; but the actinal pole is about 3·5 mm. below this. The under surface is excavate to about 5 mm., so that the length of the polar axis is about 10 mm. The specimen does not appear to have undergone more compression along this axis than it was capable of effecting spontaneously during life.

[1] Geol. Mag., n.s., Dec. IV, Vol. V, pp. 543–548, pl. xxi; Dec., 1898.

[2] To dispel possible perplexity, it may be said at once that Forbes' measurements are very inaccurate, sometimes inexplicably so.



J. GREEN PHOTO., F. A. B. DEL. MORGAN & KIDD COLLOTYPE.

EDRIOASTER BUCHIANUS.

On the Upper Surface (Pl. VIII, Fig. 1), five Radial Grooves proceed fairly straight to a distance of 13 mm. from the actinal pole. They then rather suddenly bend in a dextral or solar direction, and, at about 34 mm. from the actinal pole, pass on to the under surface of the theca (Pl. VIII, Figs. 2 and 3); here they continue along the edge until they have attained a distance of about 46 mm. from the actinal pole, when they terminate. The width of a groove in the proximal half of its course is 5·5 to 6 mm.; where it bends over to the underside, the width is about 5 mm., and gradually tapers to 2·5 or 2 mm., after which it is rapidly rounded off.

Of the five grooves, the anterior is the most perfectly preserved. In its proximal half it forms a rather deep V with slightly concave sides, as shown in section, Fig. 1. On the sides are ridges, passing outwards from the median line at an angle that varies with the curvature of the groove, but is never far from a right angle (Pl. X, Fig. 6). These ridges represent the sutures between the flooring-plates. Each ridge passes up to a prominence of somewhat ovoid outline, broader at the end next the groove; the side of the prominence towards the actinal pole has a gentler slope than the side away from it, so that the prominence as a whole seems to pass outwards in an abactinal direction. The depression between adjacent prominences is continued as an exceedingly slight concavity down the side of the groove to the middle line; slight though it be, it is observable in some parts where the sutural ridges on either side cannot be detected. The prominences, and consequently the sutural lines, on the two sides of the groove do not actually alternate; neither do they quite correspond. Therefore the ridge that may, in places, be seen at the bottom of the groove, representing the suture between the flooring-plates of the two sides, bends alternately to either side; in the tract figured (Pl. X, Fig. 6), a long stretch towards the right (of the figure) is followed by a short stretch towards the left.

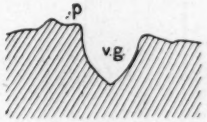


FIG. 1.

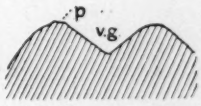


FIG. 2.

Sections across the internal cast of the anterior groove, both as seen from the oral side; × 4 diam. *v.g.* impression left by flooring-plates of subvective groove. *p.* matrix rising up into the pore between adjoining flooring-plates.

FIG. 1, from proximal region of groove.
FIG. 2, from more distal region, just on the periphery or ambitus of the fossil.

The distal region of any groove deviates from the structure just described only in the proportionately less depth of the groove, in the more pronounced alternation of the plates, and in the relative elongation of the prominences, which here merge more gradually into the sutural ridges. (See section of cast, Fig. 2).

A wax squeeze taken from the impression of the distal region of a groove (e.g. the left posterior, Pl. X, Fig. 7) restores the appearance

formerly presented by the now vanished test as seen from the outside. In this region we see the flooring-plates rising slightly above the interradial areas, then presenting a narrow flat surface, then dipping down in a slightly convex curve to the middle line of the groove. The groove is less deep than in the internal cast, which means that the flooring-plates were thicker in the middle of the groove than at its margins. Between the flooring-plates, where they bend downwards, are elongate slits, wider towards the margins of the groove; these correspond to the prominences of the internal cast.

The right anterior and left posterior grooves are still filled in places by portions of matrix; and the hollows between this matrix and the internal cast enable one to reconstruct a section of the groove based on actual measurement. Fig. 3 is taken from the left

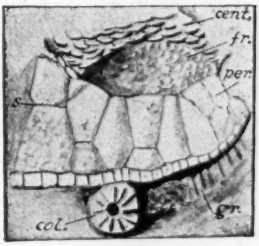
FIG. 3.—View of the left posterior groove, as preserved in the fossil. × 4 diam. *ext.* matrix filling the exterior of the groove. *int.* matrix filling the interior of the test. *gr.* groove on the surface of the latter. *p.* matrix filling pores between the flooring-plates. *p'.* scars where the same has been broken away.

posterior groove, at 5·5 mm. from its distal end. Here the plates are about 1 mm. thick at the edge of the groove, but thin considerably towards the middle line.

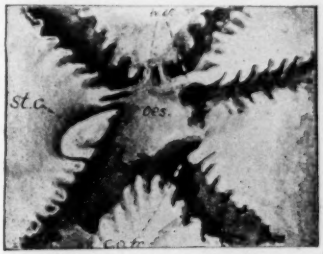
A good idea of the appearance of the groove as seen from the inside of the test is obtained from a wax squeeze of the internal cast (Pl. X, Fig. 5).

Forbes describes the "margin of the" grooves as composed of "areal or interambulacral plates bearing 2–3 short elevated transverse ridges, each of which points to the origin of an ambulacral plate, short and oblong; a double series of these ambulacral plates form the canal." It is hard to believe that Forbes did not understand he was dealing with an internal cast; yet this seems to have been the case, for he proceeds to describe the external impressions of the grooves as triangular arms "composed of two rows of dove-tailing joints, with ridges at the articulations to lock into the furrows bordering the arm-canal." From this truly remarkable misconception arose an extraordinary theory as to the nature of the radial grooves and as to the homologies of the ambulacral areas in Echinoids. After half a century one need not linger over mere errors of fact in the first sentence quoted. The present description and figures will enable readers to make the corrections themselves.

Piecing all this evidence together as in Fig. 4, we see that each radial groove was composed of a double row of flooring-plates, more or less alternating, and meeting in a median zigzag line. In the proximal half of the groove the long axis of each of these plates, nearly at right angles to the middle line of the groove, measured 3–3·5 mm., and the short axis, parallel to the middle line, ·9 mm. The total number of plates along one side of a groove was about 60



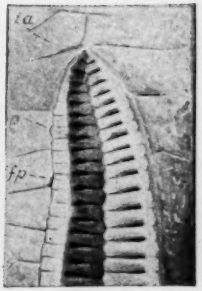
1



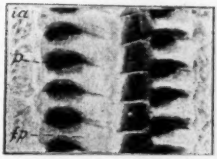
2

3

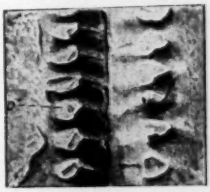
4



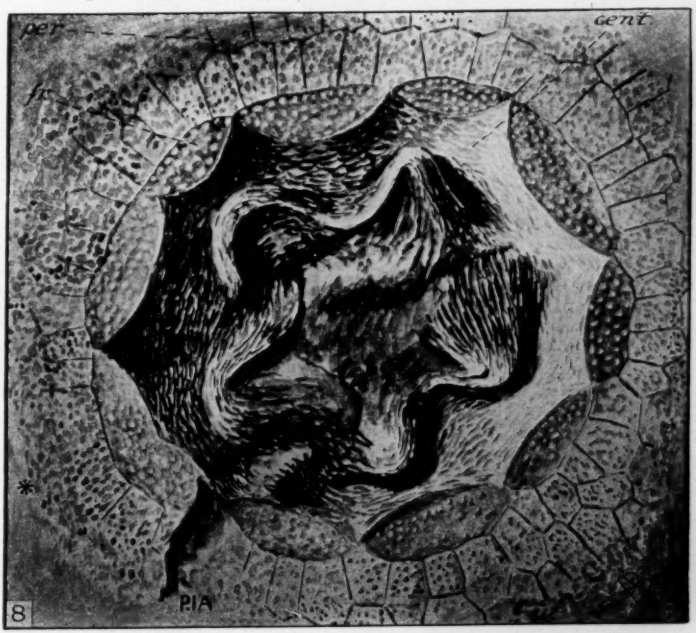
7



5



6



F. A. B. DEL. MORGAN & KIDD PHOTOTYP.

EDRIOASTER BUCHIANUS.

(certainly more than the 50 which Forbes counted). The thickness of the plates towards their outer margins was about 1 mm. The plates were continuous with the interradial thecal plates, but rather thicker; at a little distance from the edge, they bent downwards at a rather sharp angle, so as to form a V-shaped trench with slightly convex sides. Seen from the inside the plates formed a ridge, with sides at first steep, then gradually rounding over.

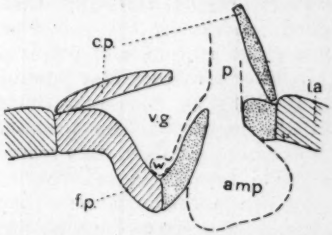


FIG. 4.—Reconstructed section across a subvective groove. × 6 diam. Compare with Fig. 1 on p. 195, and Fig. 3 on p. 196. The relations of the covering-plates are inferred from *Edrioaster Bigsbyi*. The position of the perradial water-vessel and its branch to the podium is deduced from the remains of *E. Bigsbyi* and the present species. Natural suture-surfaces are dotted; cut surfaces are ruled diagonally; supposed soft parts are in broken outline. *v.g.* subvective groove. *c.p.* covering-plates. *f.p.* flooring-plates. *i.a.* interambulacrals. *w.* perradial water-vessel, connected by a branch with the podium, *p.* *amp.* ampulla connected with the podium through the pore.

The adjacent sides of the plates were excavate so that pores were formed between them. Thus the groove was fringed with a row of pores on either side. These pores lay, not at the extreme margin, but just where the plates bent downwards; they passed outwards at an angle sloped away from the actinal centre; they were wider in the proximal portion of the groove, and more elongate in the distal portion. We may infer from the as yet undescribed structure of *Edrioaster Bigsbyi*, that the groove was roofed by covering-plates, which rested on the flattened border. But these covering-plates must have been detached and washed away before the theca was imbedded, since no traces of them remain.

Around the Actinal Pole the form of the internal cast is rather complicated (Pl. X, Fig. 2). The grooves curve down towards the pole, and at 2 or 3 mm. from the pole itself they bend downwards sharply. The central region is occupied by an irregularly shaped mass of matrix, with a broken surface about 3·5 mm. below the highest point of the cast. This mass probably represents the œsophagus. It is surrounded by a channel or, as it were, a moat, into which the down-bent grooves lead. At certain points, however, this moat is bridged by matrix, and in the two rays of the left side the extreme proximal ends of the grooves are similarly bridged. These bridges look like continuations of the prominences or infillings of the proximal pores. In the posterior interradius is a similar lump of matrix, mistakenly alluded to by Forbes (op. cit., p. 522) as "the projection which bore the anus." This is separated from the œsophageal

matrix by the moat, and is itself bordered on its outer side by a semicircular channel, which dips down on each side to join the moat; just at those points, this channel is very nearly bridged by projections from its enclosed matrix almost joining the proximal prominences of the adjacent rays. Owing to the bridging and overhanging of the matrix, it is impossible to obtain a satisfactory wax squeeze of the channels; but, translating the appearances into the original stereom structures, we infer that the mouth was central and roughly five-lobed, widest on the posterior side, and that it was surrounded by a stout ring of stereom, over which the food-grooves passed. This latter structure may possibly be that described by Salter (op. cit., p. 291) as "a great thickening of the oral ossicles, just within the mouth." The proximal or adoral pores were connected with one another above this stereom ring, but below the outer theca, so as to form a closed ring-canal (hydrocircus) around the mouth. In the posterior interradius was a madreporite or hydropore-plate, the inner surface of which formed a semicircular projection for the attachment of the upper end of the stone-canal. This was more or less directly connected with the ring-canal. The existence of pores along the radial grooves almost certainly implies the presence of podia, as well as of perradial water-vessels connecting the latter with the ring-canal. But the specimen does not afford satisfactory evidence as to the position of the perradial vessels.

The shape of the Interradial Areas has been figured by Forbes (op. cit., pl. xxiii, fig. 5), but the arrangement of the plates thus represented, though not ridiculous, is imaginary so far as details are concerned. His drawing, however, presents a certain resemblance to the left anterior interradial area, here refigured (Fig. 5). This

Fig. 5.

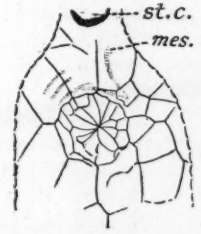


Fig. 6.

Fig. 5.—Arrangement of plates in left anterior interradius. Nat. size.
Fig. 6.—Arrangement of plates in upper part of posterior interradius. Nat. size. *st.c.* depression caused by stone-canal. *mes.* depression perhaps caused by mesentery.

shows the marks left by the plates pretty clearly, and indicates that they were irregular polygons of various sizes, apparently not imbricate. The only regularity visible in their arrangement here is a band of plates bordering the right side of the area, and passing across it at the lower edge of the theca, while another less regular band runs parallel to, and on the inner or left side of, this outer one. Down to and including these bands, there were 36 plates in the left anterior interradial area. The greatest width of this

area is 13·75 mm.; that of the posterior area is 16·5 mm. The latter also tapers less rapidly towards its actinal end, where the hydropore was situated.

The greater width of the posterior interradial area (Fig. 6 and Pl. VIII, Fig. 1) is due to the anal opening, which lay in this area about half a millimetre to the left of its middle line and at 11 mm. from the actinal pole. The anal pyramid ("ovarian pyramid" of Forbes) was not a regularly constructed pyramid surrounded by a definite rim, but was a roughly circular area of about 6·25 mm. in diameter, the plates of which appear to have risen from under the edges of the surrounding interradials. The plates contained within this circle seem to have been irregularly disposed in two circlets. The plates of the outer circlet were not so long as those of the inner. These latter were roughly triangular and met in a central point, where doubtless was the anus; the sutures indicate their number as 11, although Forbes estimated them at only 5. The anal pyramid can hardly be described as raised; but above it, and half surrounding it, is a semicircular depression with three concentric wrinkles plainly marked on its left side. Immediately on the right of the anus, the test is not depressed. In the adjacent (r. post.) interradius there is a slight elevation of the theca at this level, clearly shown in the side-view (Pl. VIII, Fig. 2). The wrinkled depression in the anal interradius may be ascribed to the contraction after death of some internal structure, presumably the mesentery attaching the stone-canal to the theca. The slight swelling that curves round from the anus may indicate the course of the rectum; and this would imply that the gut had a dextral coil. Jaekel also has expressed this view (op. cit., p. 46).

The Under or Abactinal Surface of the theca (Pl. VIII, Fig. 3, and Pl. IX) is partly bounded by the dextrally curved ends of the radial grooves, which, as seen from below, of course appear sinistral. The excavate space included by these may be divided into three regions, which, proceeding from without inwards (i.e. from oral to aboral), are as follows:—

(1) Peripheral Area.—A closed ring formed by small polygonal plates like the interradials, with which they are in fact serially homologous. These plates are roughly arranged in rows continuing the spiral twist of the grooves. They are a little smaller than the majority of the interradials, and their long axes are directed more or less radially to the vertical axis of the theca.

(2) The Frame.—A closed ring of 11 thicker and larger plates, with their long axes tangential to the vertical axis of the theca. Their outer margins are slightly scolloped by the sutures with the plates of the peripheral area; the inner margin of each forms a curve, convex towards the aboral pole. These plates seem to alternate in size, a smaller plate corresponding to each interradius and a larger to each radius. Two plates go to the wider posterior area. Too much stress, however, must not be laid on this slight appearance of regularity. These plates were ornamented with small tubercles, the traces of which are seen on both the cast and

the impression, more pronounced than those left by the interradials of the actinal surface.

(3) Central Area.—The whole space within the frame is still covered in the cast by what appears to have been a flexible

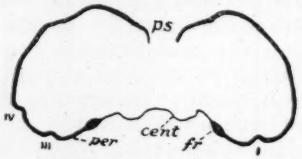


FIG. 7.—General section across the theca of *Edrioaster Buchianus*, about in the transversal plane. Natural size. i, iii, iv, three subvective grooves (compare Plate VIII). *ps*. peristome, the thickening of the circumœsophageal ring not shown. *per*. peripheral area of the abactinal surface. *cent*. central area of same. *fr*. frame surrounding the latter.

integument, in which were deposited minute, loosely calcified, imbricating plates. The imbrication is such that the outer edges of the plates are directed away from the abactinal pole. The exact arrangement of this, and its relation to the surrounding plates, are, however, best made out from a wax squeeze (Pl. X, Figs. 1 and 8) of the impression (Pl. IX).

Forbes speaks of this central portion as a "tough membrane," over which "from the centre radiating lines, with the appearance of having been caused by vessels, proceed, dividing in their course . . . The markings . . . resemble those of *Ischadites*." There can be no doubt, now that we know the structure of other Agelacrinidæ so much better than Forbes could, that these lines are merely the edges of imbricating plates. This was fully recognised by Salter (op. cit., p. 291).

Forbes' view is here mentioned in order to explain his next sentence. "The plates immediately bordering it [the membrane] are rather larger than the others, and all the plates of the base are marked with twin pore-like dots, connected by a groove." By "all the plates of the base" we must understand, not the minute imbricating plates of the membrane, but the 11 plates forming the frame, and the smaller plates of the peripheral area. Forbes' pl. xxiii, fig. 7, shows these diplopores on one of the frame-plates, but not on the membrane, while the peripheral plates are only drawn in outline. I have been quite unable to distinguish any structure at all resembling the diplopores so clearly described and figured by Forbes; there is nothing more than the tuberculation already referred to. Salter says, "The surface of the plates [in general] is granular, but I can see no trace of spines; nor can I see the chain-like pairs of pores on the puckered membrane, as figured by Forbes in his fig. 7. I think the artist has been deceived by the imbrication of the small calcareous plates which covered this surface." The chief conclusion to be drawn from these bewildering remarks is that Salter did not take the trouble to understand the clear description and figure of his predecessor. Salter's statement,

however, was repeated in modified language by Etheridge (op. cit., p. 482), and it may therefore be considered that two palæontologists of repute were, as I am, unable to see the diplopores described by Forbes and drawn by C. R. Bone.

The most important features of the abactinal membrane are 5 prominences or evaginations of it. They form a fairly regular pentagon, each corresponding to an interradius, but they bear no evident relation to the angles of the central area. Each evagination has a rounded U-shaped margin, the apex directed away from the thecal axis. The raised margins are not absolutely continuous. Within the margins the membrane is again depressed, and just in the middle, about the actinal pole, it cannot be traced in either cast or impression. Possibly it was here very thin and contained no imbricating calcareous plates. There is, however, no evidence that there was either a stem-attachment, as Forbes thought, or any opening from the gut or the body-cavity to the exterior.

These evaginations of the aboral membrane, alluded to by Forbes as "prominences" (p. 522) and "peduncles" (p. 538), received another explanation from Wyville Thomson.[1] He writes (p. 110): "In the specimen of Agel. Buchianus (Forbes), in Jermyn Street, there is a rudely pentagonal stamp on the apical surface, which is probably the impression of the wide base of a pyramid of jaws like that of Echinocystites, on the inside of the coriaceous integument." This is very incorrectly expressed, and were it not for some remarks by Salter (op. cit., pp. 290, 291), would be unintelligible. By "the pentagonal stamp," Thomson seems to have meant, as Salter says, "the five indentations figured by Forbes, fig. 6," i.e. indentations not on the apical surface, but on the impression of that surface, and therefore not really indentations but prominences. Salter, attempting to improve on Thomson, speaks of them as "large buccal teeth . . . which must, I suppose, represent the 'lantern' in the *Echinus*."

To this interpretation of the prominences there are objections of three distinct kinds. First, the specimen, though it shows traces of the circumoral ring plainly enough, shows within or below this ring no traces whatever of jaws or teeth. Secondly, the buccal armature of *Palæodiscus* would not make an impression of this nature or in this position, while that of *Echinocystis* is not large enough to make any such impression at all.[2] Thirdly, it is inconceivable that an Echinoderm of distinctly pelmatozoan type, with mouth upturned and with deep subvective grooves, can have had any use for stout biting jaws; even if descended from a gnathostomatous Echinoid (a quite absurd supposition) it would have lost its jaws before attaining its present habit and structure.

The meaning of these five extrusions of the aboral membrane must be sought among other Pelmatozoa. They must have been

[1] C. Wyville Thomson, "On a new Palæozoic Group of Echinodermata": Edinburgh New Phil. Journ., N.S., vol. xiii, pp. 106–117, pls. iii, iv; Jan., 1861.

[2] See W. J. Sollas, "On Silurian Echinoidea and Ophiuroidea": Quart. Journ. Geol. Soc., vol. lv, pp. 692–715; Nov., 1899.

made by some system of organs that had undergone division into five, and had the pentameres interradial. The stomach, gonads of Echinoid type, and water-vascular system seem therefore to be excluded, while the chambered organ of crinoids is forcibly suggested.

It is clear that the frame of 11 large plates gave some rigidity to the base, while within this the membrane was very flexible, capable of extension and contraction. These arrangements may have served a twofold purpose. If the theca were compressed by any external agent, the soft parts and the fluid contents of the cœlom would have been squeezed out into this extensile sac, which thus acted as a safety-valve. Or the vertical mesenteries of the cœlom may have been attached to it, and, developing muscles as in Echinothuridæ, may have been able to withdraw it within the frame; if the outer edge of the theca were closely apposed to the ground, the effect of this would be to create a vacuum and so hold the creature in its position like a limpet. In the dead animal, when the tissues shrank, the aboral membrane was naturally pulled upwards, and at the same time other parts of the theca were pulled inwards. Hence arose the stretching of the membrane over the internal (? chambered) organs, in the same way as the wrinkled depression already noticed in the posterior interradius. Jaekel's opinion that the central area of the abactinal surface was fixed (*aufgewachsen*) on a not quite hard bottom, does not seem in accord with the shape of the theca or with the sharp definition of these five lobes.

Other Specimens.

The various stem-fragments ascribed by Forbes to this species can, as already noted by Salter and Etheridge, have had nothing to do with it. They were found in the same stone wall, but not in juxtaposition with the theca. Neither can the 4-rayed impression so badly represented in Forbes' pl. xxiii, fig. 14, be regarded as "the impression of the base, probably of a similar cystidean."

There was found, however, one other fragment, which I am unable to fit on to the type-specimen, and therefore regard as indicating the existence of another individual. It is an impression of part of an ambulacrum, 16 mm. long, and of portions of the adjacent interambulacra, one of which shows very clearly the markings produced by the ornament of the plates (Pl. X, Fig. 3).

No other specimen of this species is known.

Systematic Position.

Forbes called this species *Agelacrinites Buchianus*, comparing it first with the specimen discovered by Bigsby, and described and figured by G. B. Sowerby in the Zoological Journal (vol. ii, pp. 318–320, pl. xi, fig. 5, 1826), and afterwards named *Agelacrinites Dicksoni* by E. Billings (1856); and secondly with *Agelacrinites hamiltonensis*, Vanuxem, which is the type of the genus. Forbes considered it as a Cystid, allied to the Echinoidea.

Salter (op. cit., p. 290), while retaining the species in *Agelacrinus*, considered it as more allied to the species described by Billings as

Edrioaster Bigsbyi, 1858. In the list on p. 262 of the same work it is actually called "*Edrioaster Buchii* (*Agelacrinus*, Forbes)." The same is the case in Etheridge's revision of Salter (pp. 481 and 395).

Salter's opinion is abundantly justified not only by the details of the present paper, but by the new facts concerning *Edrioaster Bigsbyi*, which will form the subject of the next study. To that it is better to postpone the diagnoses of the genus and of the present species.

EXPLANATION OF PLATES VIII, IX, AND X.

EDRIOASTER BUCHIANUS.

[All the figures are from the type-specimen in the Museum of Practical Geology, except Pl. X, Fig. 3, which is from a fragment associated with it. Plates VIII and IX are based on photographs by Mr. J. Green; the figures of Plate X are drawn directly from the specimens or from wax squeezes thereof. The figures of Plates VIII and IX are magnified two diameters; those of Plate X are enlarged to the extent stated under each. Difficulties of lighting have rendered impossible a rigorous maintenance of the standard orientation; where doubt might have arisen the position of the anal interradius has been marked by a *.]

PLATE VIII.—The internal cast.

FIG. 1.—Actinal surface, showing peristomial and anal areas clearly, and the subvective grooves here occupying an almost strictly radial position and marked i–v from left posterior to right posterior.

FIG. 2.—Side view, showing the curvature of the subvective grooves. The anterior groove (iii) passes across the middle of the figure. The plates of the right anterior interradius (between iii and iv) are fairly distinct.

FIG. 3.—Abactinal surface, showing in its central area a portion of the original test (compare Pl. X, Fig. 8). The numbers i–v here correspond to those of Fig. 1, and mark the radii, while the subvective groove corresponding to each number is now seen to have passed through fully one-fifth of the circumference away from it: e.g. the anterior groove (iii of Fig. 1) now comes into the right anterior radius (iv). Close to number ii some matrix fills the groove, and on this is the impression of a columnal of some crinoid or cystid.

PLATE IX.—The external impression of the abactinal surface. The upper figure is lit from the right hand, the lower figure from the left hand. These figures, with Fig. 3 of Pl. VIII, give the evidence on which Pl. X, Fig. 8 is based.

PLATE X.—Enlarged details.

FIG. 1.—A wax squeeze from a portion of the impression of the abactinal surface, showing accurately the relations of the plates; × 3 diameters. Compare Forbes, pl. xxiii, fig. 7. *cent.* small plates of the central area. *fr.* a frame-plate. *per.* plates of the perradial area. *s.* suture between two of the latter, apparently crenulate. *gr.* portion of left anterior subvective groove. *col.* columnal lying on matrix that fills a part of this groove.

FIG. 2.—The peristomial region of the internal cast, slightly diagrammatised, and seen from right posterior interradius; × 2 diam. *st.c.* a depression where a semicircular ridge on the inside of the test is supposed to have supported the stone-canal; the matrix within this would thus have underlain the madreporite. *oes.* matrix filling the œsophagus. *c.o.fr.* hollow space surrounding the latter and presumed to have been occupied by a circumœsophageal frame of plates (modified flooring-plates). *w.v.* strands of matrix bridging over the space just mentioned; they seem to be serially homologous with the podial or pore scars, and may represent water-vessels connecting the adoral podia with a circumoral water-ring.

FIG. 3.—Interambulacrals showing vermiculate ornament and raised, slightly crenulate suture-margins. From a wax squeeze of a fragment associated with the type. × $\frac{6}{5}$.

FIG. 4.—Flooring-plates in the distal region of the left anterior groove, drawn from a wax squeeze of the external impression. × 6 diam.

FIG. 5.—Portion of the anterior groove as seen on the inside of the test, drawn from a wax squeeze of the internal cast; × 5 diam. *ia.* interambulacrals. *p.* pores for the passage of the podia or of the ampullæ from the podia. *f.p.* flooring-plates. The proximal end is uppermost in the drawing.

FIG. 6.—The internal cast of part of a subvective groove; the complement of Fig. 5. × 5 diam. *p'.* projecting scars of matrix that filled the podial pores.

FIG. 7.—The distal end of the left posterior groove, from a wax squeeze of the external impression; × 4 diam. Lettering as in Fig. 5.

FIG. 8.—The central part of the abactinal surface, from a wax squeeze of the external cast (Pl. IX), slightly diagrammatised, since details are often obscure in the specimen; × 3 diam. *per.* peripheral area. *fr.* frame. *cent.* central area, with its flexible plated membrane, raised in five interradially situate lobes. * position of posterior (anal) interradius. P.IA. the meridian in which plates of the posterior interradius (i.e. posterior interambulacrals) pass from the actinal to the abactinal surface and merge with the peripheral plates of the latter.

II.—Bala Lake and the River System of North Wales.

By Philip Lake, M.A., F.G.S.

Introduction.

THE evolution of rivers and the origin of lakes have recently attracted a considerable share of attention; and the principles which should guide us in tracing the development of a drainage system have been expounded by several authors, both in England and in America.

Little, however, has been written on the lakes and rivers of North Wales. In 1876 Ramsay,[1] who was one of the pioneers in questions of this kind, endeavoured to decipher the history of the Dee and of Bala Lake; and subsequently he performed a similar office for the Clwyd.[2] More recently Mr. Strahan and Mr. Morton[3] have dealt with the latter river.

A few papers,[4] also, have been written on the tarns or 'Llyniau' of Caernarvonshire; but with these we are not directly concerned.

In the following pages an attempt is made to explain the origin of Bala Lake, and to show how the river system of North Wales was established and was subsequently modified; but the formation of the Vale of Clwyd is barely touched in this investigation.

It is scarcely necessary to point out how deeply I am indebted to the writings of Mr. Marr, to which, in fact, whatever there may be of value in my labours is primarily due. For although the present drainage system of North Wales differs greatly from that of Cumberland and Westmoreland, yet in some respects the resemblance is so close that it is Mr. Marr's work in the Lake District which has enabled me to attempt an interpretation of the river

[1] Quart. Journ. Geol. Soc., vol. xxxii (1876), pp. 219–229. See also Mem. Geol. Surv., vol. iii (1881), 2nd ed., pp. 314–323.

[2] Mem. Geol. Surv., vol. iii (1881), 2nd ed., pp. 306–313.

[3] G. H. Morton: Proc. Liverpool Geol. Soc., vol. viii (1897–98), pp. 32–65, 181–204. A. Strahan: Geol. Mag., 1899, pp. 111–117.

[4] W. W. Watts: Brit. Assoc. Reports, 1895, pp. 683, 684. W. A. Brend: Geol. Mag., 1897, pp. 404–407. J. E. Marr & R. H. Adie: Geol. Mag., 1898, pp. 51–61.

system of North Wales. Mr. Marr, however, finds no evidence of the differential movements which seem in Wales to have played so important a part in modifying the original drainage system.

My thanks are also due to Mr. A. L. Hall, of Caius College, Cambridge, and to Mr. J. B. Scrivenor, of Hertford College, Oxford, for invaluable assistance in sounding Bala Lake; and I am, besides, under obligation to Mr. Hall for help in other portions of the work.

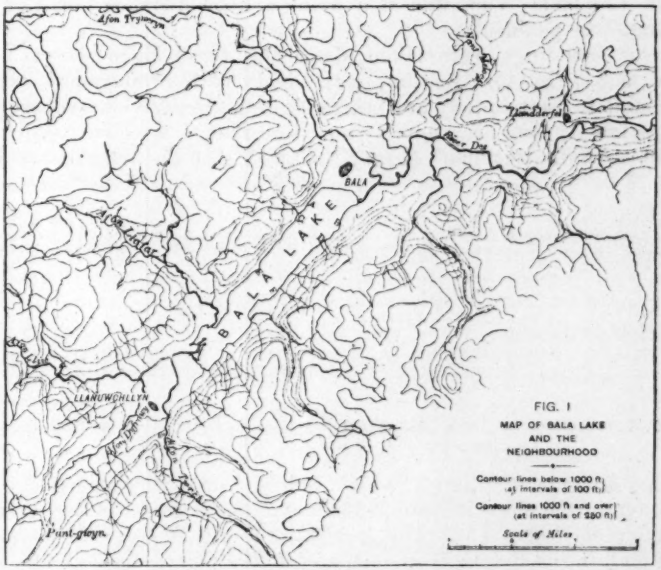

BALA
BALA LAKE
LLANUWCHLLYN
Pont-glyn.
FIG. 1
MAP OF BALA LAKE AND THE NEIGHBOURHOOD
Contour lines below 1000 ft. (at intervals of 100 ft.)
Contour lines 1000 ft. and over (at intervals of 250 ft.)
Scale of Miles.

FIG. 1.

Contours below 1,000 feet indicated by dotted lines.
Contours 1,000 feet and over indicated by continuous lines.

Topography of Bala Lake and of the valley in which it lies.

Bala Lake (see Fig. 1), the largest natural sheet of water in Wales, is nearly four miles long and about half a mile wide. It is oblong in shape and unusually regular, the two sides being remarkably straight and parallel, so that the width is nearly uniform throughout. The straightness of the sides is interrupted only by the peninsulas of Llafar, Llangower, and one or two smaller points; and all of these are mere tongues of alluvium. At each end there is a wide alluvial plain, and the lake owes its symmetry partly, but not entirely, to these alluvial deposits.

On February 19, 1885, the surface of the water was determined by the Ordnance Survey to be 529·9 feet above Ordnance Datum; [1]

[1] Merionethshire (6 inches to 1 mile): Quarter-sheets xxii S.W., xxii N.W., and xxii N.E.

and on August 3, 1899, in a dry season, Mr. Hall and I found it to be 15·3 feet below B.M. 543·7 (about a mile south-west of Llangower), or 528·4 feet above O.D. The level of the water, therefore, seems to vary but little, and it may be taken as about 530 feet above the sea.

The depth of the lake is stated by Ramsay to be about 130 feet.[1] On August 1, 1899, Mr. Hall, Mr. Scrivenor, and myself took a series of soundings, and the greatest depth which we measured was 126 feet. This was at a point a little distance north of the Llangower peninsula.

Our soundings were taken along the three lines shown upon the map (Fig. 1). As they were made with 'water-cord,' which is liable to stretch, they are not exact, but (corrected by subsequent experiment) they are probably not more than a few feet out in any case. All the sections[2] (Fig. 2) showed that the sides of the lake

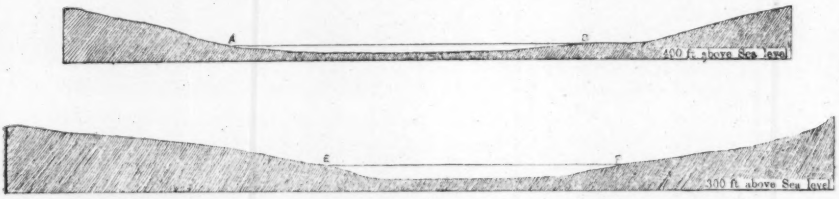


Fig. 2.—Sections of Bala Lake along the lines A–B and E–F in Fig. 1. Scale (horizontal and vertical), 3 inches = 1 mile.

slope inwards at an angle, which, indeed, is not very steep; but the bottom of the slope is well defined, and the central portion of each section is nearly flat. The maximum depth in the line A–B was 66 feet, in the line C–D 77 feet, and in the line E–F 126 feet. The floor of the lake, therefore, appears to slope from north-east to south-west, that is to say, in a direction opposite to the present flow of the water. It would, however, require a more extended series of observations to prove that this slope is continuous.

In the paper already mentioned,[3] Ramsay assumes that there never could have been any other outlet for the water of the lake than the channel of the Dee; and because the Dee flows over rock *in situ* at a higher level than the bottom of the lake, he concludes that the lake must lie in a rock basin. In the light of Mr. Marr's recent researches on the tarns and lakes of Cumberland and

[1] Quart. Journ. Geol. Soc., vol. xxxii (1876), p. 219.

[2] Our positions were determined by compass bearings from the shore, and have no pretensions to precise accuracy. The section A–B and the south-eastern half of the section E–F are probably correct; but in the north-western half of the section E–F the angles of intersection were somewhat acute, and the positions of the soundings are therefore not so accurately fixed.

[3] "On the Physical History of the Dee, Wales": Quart. Journ. Geol. Soc., vol. xxxii (1876), pp. 219–229. See also Mem. Geol. Surv., vol. iii (1881), 2nd ed., pp. 314–323.

Westmoreland,[1] it is impossible now to maintain this view without a closer examination of other possible outlets.

Now, although Bala Lake empties itself through the Dee, which flows in an easterly direction from its north-eastern end, this is not what the general topography of the district would lead us to expect. The lake does not lie in the continuation of the Vale of Edeyrnion (as the valley of the Dee between Llandderfel and Corwen is called); but it lies in a very distinct and well-defined valley which runs from the sea at Barmouth in a north-easterly direction to the town of Bala; and this valley is entirely shut off from the Vale of Edeyrnion by a ridge of hills, except for the narrow gorge through which the Dee now flows. This great valley is in the line of the Bala fault, and from Dolgelly to Bala its direction is S.W.–N.E., which is precisely that of the lake; while the general direction of the Dee for several miles after leaving the lake is nearly west to east.

It is true that the actual watershed crosses the valley at Pantgwyn, and that on the one side the waters flow into Bala Lake and thence to the Dee, while on the other side they flow into Afon Wnion and finally into the estuary of the Mawddach. But the watershed forms no feature in the valley, and the slope which determines the direction of flow is so slight that it requires a very careful examination of the streams to discover the position of the water-parting. The floor of the valley in no place rises to a greater height than 774 feet above the sea, i.e. about 374 feet above the bottom of the lake. The depth of the valley near this point is entirely out of proportion to the size of the little rivulets which now flow in it.

Continuing the line of the valley in which Bala Lake lies, it leads us in a north-easterly direction, not along the course of the Dee, but into the valley which is now occupied by Nant Meloch and its tributary from Cors-y-Sarnau. This is a stream which flows from north-east to south-west, and which would enter the lake near Bala, were it not that before it reaches that point it is suddenly deflected almost at right angles, so as to join the Dee at Melin Meloch.

If the gorge near Llandderfel were blocked, this stream would flow into Bala Lake, and Bala Lake would empty itself into the Wnion; and we should have a continuous flow of water down what is now undoubtedly a continuous valley running from north-east to south-west.

From these topographical considerations alone, it appears probable that the drainage of the district originally flowed in this direction, and that the present outlet of the lake is of subsequent formation. In favour of this view it may be noted that at the foot of the lake there is an alluvial plain, which is even more extensive than that which is now being formed at its head; and also that the floor of the lake appears to slope from north-east to south-west.

[1] See, especially, "The Tarns of Lakeland": Quart. Journ. Geol. Soc., vol. li (1895), pp. 35–48. "Additional Notes on the Tarns of Lakeland": ibid., vol. lii (1896), pp. 12–16. "On the Lake Basins of Lakeland": Proc. Geol. Assoc., vol. xiv (1896), pp. 273–286.

Is Bala Lake a rock-basin?

There are only three directions in which we can leave Bala Lake and travel towards the sea without crossing the contour-line of 1,000 feet.

The first of these is north-east, up the valley of Nant Meloch, and along the road to Corwen, where the greatest height to which we are compelled to rise is 891 feet, about $1\frac{1}{4}$ mile from Bethel Inn.

The second is east, along the course of the Dee; and this is necessarily a continuous descent.

The third is south-west, along the valley of the Bala fault, where we can reach the sea without ever rising higher than 774 feet.

Elsewhere the lake is completely shut in by the 1,000 foot contour-line, and there is no reason to suspect the existence of any former outlet.

I have not examined very closely the valley of Nant Meloch; but I believe that in this direction the rocky floor rises considerably above the level of the bottom of the lake. Even now, where the bottom of the valley is 600 or 700 feet above the sea, the valley is narrow and steep-sided, and it seems improbable that the solid floor lies two or three hundred feet below the present level. The valley, however, deserves a more careful examination than I have been able to give it.

If we follow the present course of the Dee from Bala Lake, we pass first over a wide alluvial plain until we near the ridge which crosses the line of the river at Bodweni, about $2\frac{1}{2}$ miles east of Bala. Here the Dee enters a narrow and rather steep-sided gorge, and is closely hemmed in by hills of solid rock; and a little farther on, the bed itself is formed of rock at a height of about 495 feet above the sea, or 95 feet above the bottom of the lake. So narrow is the valley at this point, and so close lie the exposures of solid rock, that there seems to be no room for any drift-filled gorge; and there can be but little doubt that in this direction at least, as Ramsay pointed out, the lake is rock-bound.

South-westerly, however, along the line of the Bala fault, it is impossible to prove that the solid floor of the valley is at any point higher than the bottom of the lake. Following upwards the course of the Dyfrdwy, we find that at Tal-y-bont the stream flows over rock *in sitû* at a height of more than 600 feet. But the valley here is very wide, and for many hundred yards south-east of the stream there is nothing to be seen but drift. It is quite possible, therefore, that another channel may exist which is now concealed.

No more rock is exposed *in sitû* in the bottom of the valley until we have passed the watershed and proceeded down the other slope to Drws-y-nant-isaf. A few hundred yards below the railway station the river runs in a little rocky gorge, the floor of which is also made of rock; and the height of this floor is about 460 feet above the sea, that is to say, about 60 feet above the bottom of the lake. But at this point, exactly, in fact, where it enters the gorge, the river has left the line of the Bala fault and has been deflected

to the right; while in the direct line there is a slight depression, which is certainly filled with drift, however deep or shallow that drift may be.

Here, again, it is impossible to assert that the solid floor of the valley is higher than the bottom of the lake. And as no more rock is seen *in sitû* until we pass below the level of the lowest point of the lake, we are compelled to admit that in this direction there is no certain evidence that the lake is rock-bound.

So far, then, as this evidence goes, Bala Lake may have been formed in the same way as the lakes of Cumberland and Westmoreland. The sections show that, like them, it is a submerged river valley. Its general direction and the slope of its bed indicate that the valley of which it is a portion is the valley of the Bala fault. Originally, no doubt, the waters drained south-westward into the sea at Barmouth (or, perhaps, at Towyn). But the channel was subsequently blocked, and the drainage of the upper portion was forced to seek a fresh outlet.

I shall, however, give reasons for supposing that, although the old channel may have been choked by drift, the reversal of the drainage was due, at least in part, to earth-movements; and that it was these earth-movements which determined the position of the watershed.

Relation of the Faults to the Valley and to the Watershed.

That the valley to which, as we have seen, Bala Lake belongs, is in the line of a great fault, has long been known; and the fault is represented on the Survey maps as passing down the middle of the lake. It lies, I believe, more nearly along the south-eastern shore, and the opposite shore coincides with the line of a second fault, which, like the former, has its downthrow towards the lake. Thus the lake lies in the continuation of a trough, and its two sides coincide or nearly coincide with the two faults enclosing the trough.

South of Pant-gwyn the valley is very narrow. Its north-western side is formed of volcanic rocks, which are usually supposed to be of Arenig age, while the south-eastern side is formed of Middle Lingula beds containing *Lingulella Davisi*. But the floor of the valley is concealed by drift and alluvium, and there is nothing to indicate the exact position of the fault which undoubtedly exists, nor is there any evidence to show whether this fault is simple or compound.

At Pant-gwyn, however, the valley opens out; the faults are much more clearly seen, and here they form a complex system which we shall now proceed to examine. (Fig. 3.)

It is, perhaps, unnecessary to give in detail the evidence on which these faults are drawn. It will almost be sufficient to say that, in general, wherever the volcanic series exists, it is conspicuously visible, and it is an easy matter to trace its boundary.

The slates below the volcanic series are also well enough exposed, but it is different with the post-volcanic slates in the valley; and as many of the exposures of these beds are difficult to find, it may be well to enumerate them.

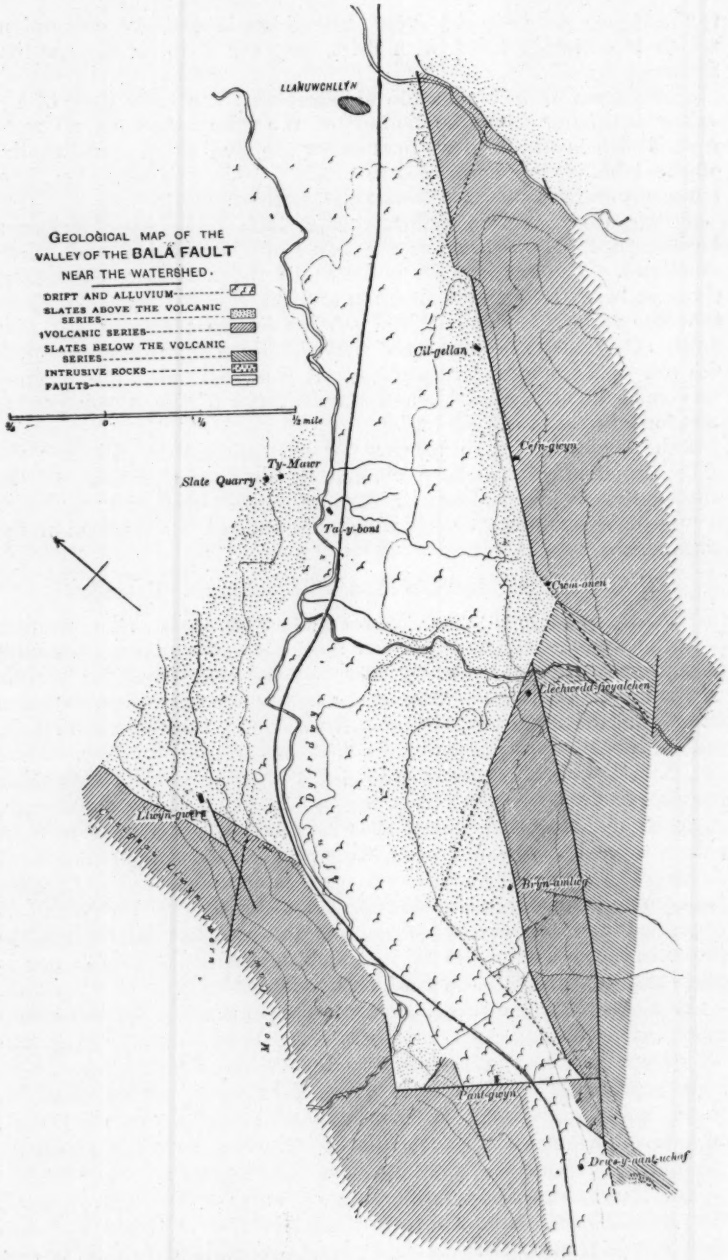


FIG. 3.—Geological Map of the Valley of the Bala Fault.

On the south-east side of the valley, these slates are visible close to the Bala fault at Cilgellan, and again between Cefn-gwyn and Cwm-onen. They, as well as all the other rocks, are well exposed in and near Afon Dwrnudo.[1] They occur also in the banks of a small stream about 300 yards below Bryn Amlwg; and again, close to the Bryn Amlwg patch of volcanics, in the streamlets near the transverse fault.

On the other side of the valley, the slates are found in the farm-yard of Pant-gwyn. They are well exposed in the triangular patch four or five hundred yards north-west of that farm; and in the Dyfrdwy they are seen to overlie the volcanic series, dipping 5° S. of E. (true) at an angle of 38°. They occur also in the quarry near Ty-mawr and in the bed of the river close to Tal-y-bont.

In the neighbourhood of Llwyn-gwern these slates are visible in several places, and the volcanic series dips beneath them. South-east of Llanuwchllyn also, in the valley of Afon Twrch, the slates and ashes are clearly shown, and the ashes dip beneath the slates; but the boundary is here more complex than is represented upon the map, being faulted by a series of little faults of which only one or two are indicated.

The north-to-south fault which lies east of Drws-y-nant-uchaf is plainly visible in the stream 300 yards above the farm, where it brings black slates (presumably Upper Lingula) on its eastern side into contact with Middle Lingula Flags (containing *Lingulella Davisi*) on its western side. The eastern is therefore the downthrow side, and as the hade is towards the west the fault is reversed. The crushing due to this fault is also seen in the little rivulet some 200 yards north-east of the farm.

The fault which is drawn between Moel Caws and Creigiau Llwyn-gwern nowhere, so far as is visible, brings beds of different character into contact with each other, and is inserted upon less evidence than the rest. But I venture to think that few who examine the remarkable little valley in which it lies will be disposed to deny the existence of this fault.

The evidence for the other faults is manifest upon the map, and need not here be recapitulated. In most cases the position and direction can be fixed with considerable accuracy, but seldom so precisely as to determine which of two intersecting faults displaces the other. It may be noted that the fault which crosses the Dwrnudo 600 yards above Llechwedd-fwyalchen is probably continued for a considerable distance in both directions.

One or two patches of intrusive rock exist besides that which is shown upon the map. Granophyre occurs on both sides of the Bala fault at several points north-east of Drws-y-nant-uchaf, but is too imperfectly exposed to be satisfactorily mapped. There are also some masses of intrusive rock on the left bank of the Dyfrdwy, near Rhyd-y-drain; but these have not yet been examined in detail.

[1] Afon Dwrnudo is the stream which flows past Llechwedd-fwyalchen.

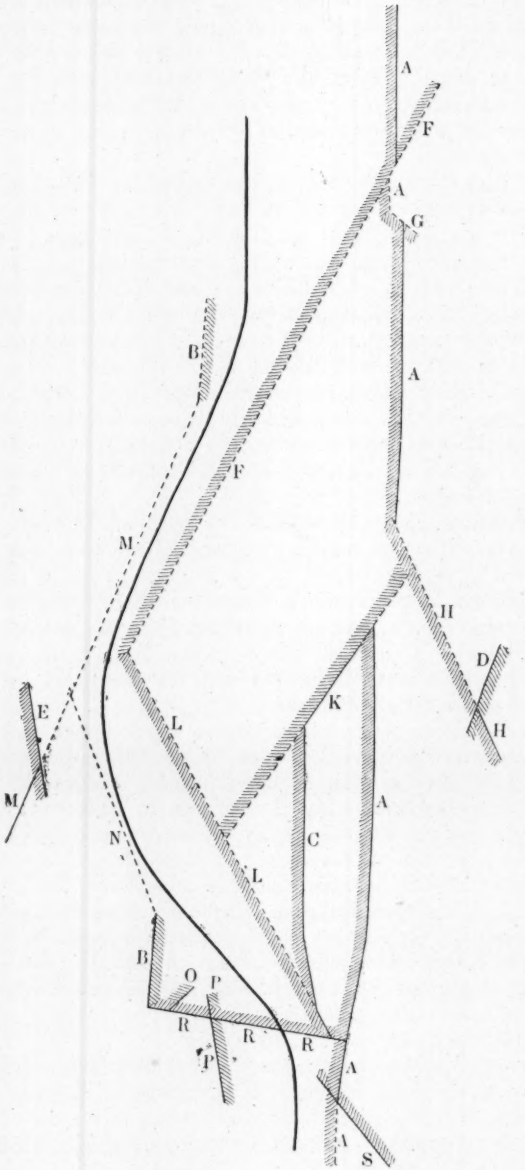


FIG. 4.—Diagram of the Bala Faults.

In the accompanying diagram of the faults (Fig. 4), the downthrow side of each (when it is known) is shaded, and the bottom of the

valley is indicated by a heavy line. Some of the faults are continued, in their probable directions, into the area which is now concealed by drift and alluvium ; and an additional fault (N) is inserted which is not shown upon the geological map. The existence of this is somewhat doubtful, but the foot of the hills is here so extraordinarily straight that I cannot help suspecting that it coincides with a line of fault.

A comparison of this diagram with the topographical map (Fig. 5) will show that the actual contour of the ground agrees very closely with the contour which would be produced by the faults, if it were determined by them alone. It is true that a few of the faults, such as that near Drws-y-nant-uchaf, have no effect upon the surface.

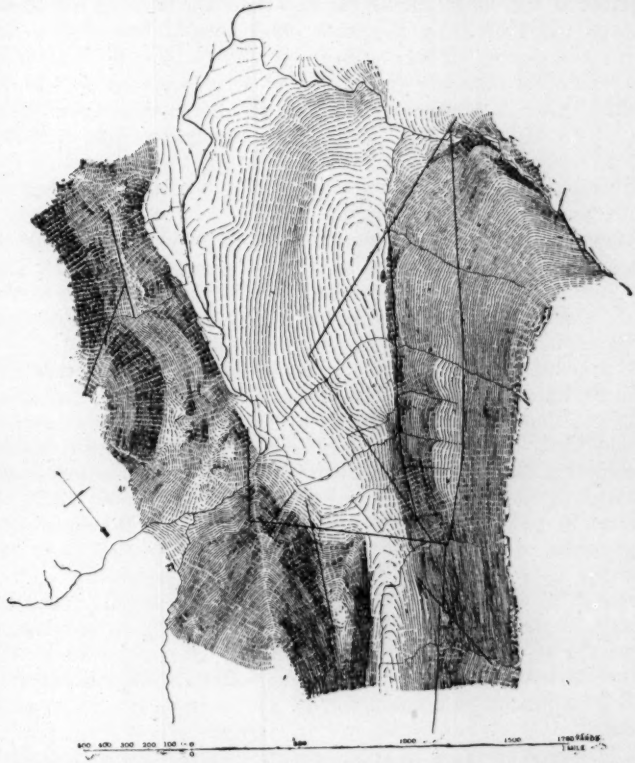


FIG. 5.—Sketch-map of the topography of the valley of the Bala Fault near the watershed.

But generally each fault is marked by a more or less sudden change of slope, and the ground on the downthrow side of the fault lies lower than that on the upthrow side. This is sometimes well shown even where the rock is similar in character on both sides of the fault. Attention may be drawn, for example, to the fault west of Pant-gwyn.

It will be observed that several of the most important faults run parallel to the general direction of the valley, some on one side and some on the other, and that in most cases the downthrow of these faults is towards the valley; the only exceptions are the faults D and E, which indeed are not parallel to the valley, but are nearly so, and are placed symmetrically with regard to it. In these two cases the downthrow is away from the valley.

There is also a series of transverse or oblique faults, and these throw down either towards Bala Lake or towards the bottom of the valley.

Except for a wide curve, convex towards the north-west, the whole of the valley north of Pant-gwyn is enclosed between the outermost of the longitudinal faults—the Bala fault (A) on the one hand and the fault B on the other; and both of these throw down towards the centre of the valley. Moreover, the fault B, if produced, coincides precisely (as is very clearly seen in the field from a position near its southern end) with the north-west shore of Bala Lake. The Bala fault is dislocated at several points, but if the northernmost portion be continued in a straight line it will be found to lie nearly parallel to the south-east shore of the lake, but some distance within the water's edge.

Without any aid from denudation these faults would, of themselves alone, form a valley very similar to that which now exists; and if we take into account the oblique faults F, M,[1] and L and the doubtful fault N, even the convex bend of the valley out of its regular course may be explained as directly due to the faulting.

The general shape of the valley is, in fact, not unlike that which the faults themselves might be expected to produce. But it must be allowed that the form produced by the faults has been considerably modified by subsequent denudation; and it is difficult, if not impossible, to determine how far the present configuration is to be attributed to the direct effect of the faults and how far to their influence in guiding denudation. The relation of the faults to the configuration of the ground is, however, so close that they must, either directly or indirectly, be the cause of that configuration.

Even if we assume that the valley has been actually formed by the faults themselves, it is by no means necessary to suppose that it is so old as, for example, the Bala fault. A comparatively small movement along this fault, perhaps long after its original formation, would be sufficient to account for all the phenomena so far as it is concerned.

The transverse fault at Pant-gwyn is particularly interesting. Its downthrow is towards the north-east, that is, towards Bala Lake; and it appears to form the southern end of the trough produced by the longitudinal faults. On the north-west bank of the valley the ground is much higher on the upthrow side of the fault than on the downthrow side. But this is not the case on the south-east bank. Yet here, near the bottom of the valley, drift on the downthrow

[1] It should be noted that there is no evidence to show which is the downthrow side of either M or N.

side is in contact with solid rock on the upthrow side, and it is possible that the fault produces its full effect upon the solid floor. However this may be, the fault coincides very closely with the watershed in the valley. No water crosses it except a single streamlet, and this rises only a yard or two away.

Whatever the reason may be, therefore, we may safely say that the valley north of Pant-gwyn lies in the trough between two faults, and that this trough is closed at its southern end by a transverse fault, which coincides with the watershed crossing the valley; and further, that many of the other faults apparently produce on the surface of the ground an effect which is similar in kind, if not in degree, to that which they produce on the strata themselves.

That these coincidences are accidental is, to say the least, improbable; and a simple explanation appears to be that the valley was blocked out, so to speak, by the faults themselves, and that the form so produced has been somewhat modified by subsequent denudation.

In advancing this view I am aware that it attributes to the faults a more direct influence upon the topography than many geologists will be disposed to allow. But although most valleys may have been carved out by rivers, it is impossible to deny that some have been formed by faults.

It may be urged that since the formation of the faults there must have been a vast amount of denudation which would obliterate their effect upon the surface. But where erosion exceeds deposition, the tendency of subaerial denudation is to accentuate rather than to obliterate inequalities. Moreover, the evidence of the age of the faults is extremely slight, and there is nothing to show that no movement has taken place along them in comparatively recent times.[1] I shall show subsequently that, however the valley may have been formed, it was probably not in existence when the drainage system of the district was first established.

(*To be concluded in our next Number.*)

III.—Plant-stems in the Guttannen Gneiss.

By Professor T. G. Bonney, D.Sc., LL.D., F.R.S.

An important paper[2] on the reputed occurrence of fossil plant-stems in gneiss of Carboniferous age at Guttannen, Switzerland, by Messrs. E. v. Fellenberg & C. Schmidt, for a copy of which I am indebted to the courtesy of the authors, closes, if their view be adopted, a comedy of errors. On this account a brief outline of the story may be of service; for it reduces this supposed relic of Palæozoic forests to a *lusus naturæ*, and, in any case, once more illustrates the truth of the saying, "we are all fallible mortals."

[1] It may be noted that Mr. C. Davison's researches on earthquakes in Great Britain seem to indicate that even at the present time slips occasionally take place along faults which are, in their origin, of very ancient date.

[2] E. v. Fellenberg & C. Schmidt, "Neuere Untersuchungen über den sogen. Stamm im Gneisse von Guttannen": Separat-Abdruck aus den Mitt. der Naturfors. Gesell. in Bern, Jahrgang 1898.

The gneiss-plant's first introduction to English literature was, I think, in 1890, when Professor Heim, in a controversial note appended to my paper on "Crystalline Schists and their relation to Mesozoic Rocks in the Lepontine Alps,"[1] cited it as a proof that gneiss of Palæozoic age existed in the Central Alps; but it was described and figured by Baltzer[2] two years earlier in the official publication of the Swiss Geological Survey. I had, however, examined the specimen when visiting the Museum at Berne in August, 1889, and can best describe its aspect and the impression it produced on me by an extract from my diary. "The rock is a purplish-grey colour, rather fine-grained as a rule, containing numerous small plates of brown mica, many white spots rather angular in outline, apparently felspar, and quartz, in the matrix. One or two quartz veins traverse the block. The rock at first sight is wonderfully like a gneiss. It has evidently been compressed, resulting in a sort of foliation or rude cleavage, with a brown slickensided look on the surfaces of the supposed organisms (cf. the Obermittweida conglomerate, Reusch's Scandinavian fossils in Silurian 'schists,' etc.). The rock does not exactly resemble any gneiss I have seen in the Alps. Though I cannot be quite sure that I detected extraneous fragments, I thought I did. The matrix varies somewhat from coarse to fine, as one traces it through the mass, and its ultimate groundmass or 'paste' has a slightly muddy look. In short, the rock reminded me very much of some of the best 'imitative crystallines' of Vernayaz, and I suspect that it is really an infolding of Palæozoic or Mesozoic 'arkose.' The tree stems are two in number, with obscure traces of what may be a third; the largest about 5 feet long by 8 inches wide; it rises in a low curve, with a sagitta of about 3 inches. There are some indications of cross markings like the stems of calamites; no ribbings or leaf-scars that I noticed. In short, they are obscure markings, but I think it more likely that they indicate vegetable remains than that the rock is a member of the crystalline series." The opinion thus formed was expressed in a note on Professor Heim's comments appended to the above-named paper.[3]

I determined, however, to make a fuller investigation of the question, and in 1891 found an opportunity of visiting Guttannen, in company with my friend Mr. J. Eccles, F.G.S. On my way from England I halted at Berne to make another examination of the specimen in the Museum. The note, written on the spot, is practically an epitome of that already quoted, with the addition that "one stem appears to have a kind of 'bark,' not graphite, but dark carbonaceous matter, as if coaly material were mixed with mud. The outer surface has a sort of brown glaze (irony) over it, and so has the inner one." At Guttannen we examined the outcrops of the supposed Carboniferous gneiss on the eastern side of the valley, with some of those on the western, together with many

[1] Quart. Journ. Geol. Soc., vol. xlvi, p. 237.
[2] Beiträge zur geol. Karte der Schweiz, Lief. xxiv (1888), pt. 4, p. 161.
[3] Quart. Journ. Geol. Soc., vol. xlvi, p. 238.

erratic blocks, including that from which the Berne specimen was said to have been taken.

This field work[1] and subsequent microscopic study of specimens strengthened my conviction that the rock was an 'arkose' of materials from crystalline rocks, and thus only an imitation of a gneiss.[2] I may add that the other possibility—that these objects were not really plants, but imitative markings, produced by earth movements in a truly crystalline rock—had been present to my mind throughout. It would have saved me from wasting my time by a journey to Guttannen, so that, if I could, I would gladly have adopted it. But the markings were accepted as plants by the experts of the Swiss Survey,[3] and, so far as I could form an opinion, on good grounds, while the clastic structure of the rock on the whole appeared to be original rather than superinduced. Moreover, the grounds on which Herr Schmidt claimed the rock for a true gneiss appeared to me, as I pointed out in my paper,[4] defective in more than one respect.

Still, though this visit to Guttannen strengthened my conviction, microscopic study of the specimens did not, as I had hoped, place the matter beyond all question. So in the Summer of 1895 I again visited Guttannen, this time in company with my friend the Rev. Edwin Hill, F.G.S., and now more especially examined the western flank of the valley. Everywhere the so-called Carboniferous gneiss had a grit-like aspect, including a not unfrequent change in coarseness perpendicular to the occasional banded structure. In one place we found a thin band of rock resembling a dark phyllite, but no conglomerate. We traced the 'Carboniferous gneiss' northwards nearly up to its junction with the ordinary gneiss of the district, the difference between them being very marked. Though the field work strengthened me in the view which I had already expressed, complete demonstration was again wanting and was not supplied by a microscopic study of the specimens collected. Among other things, the supposed phyllite band exhibited such indications of crushing as to make it an untrustworthy witness.

I determined, however, to make a third attempt to obtain decisive evidence. According to the Swiss geological map this zone of 'Carboniferous gneiss' crosses the Urbach Thal, just about the foot of the Gauli Glacier. So in the Summer of 1897 I planned a visit to this locality in company with Mr. J. Parkinson, F.G.S. The walk to the foot of the glacier, from Im Hof, the nearest halting-place, and back, takes about eight hours, so our time for studying the gneiss was rather limited. The result of this[5] and of subsequent microscopic examination of specimens was

[1] About a month later I visited Vernayaz to look once more at the well-known Carboniferous infold, parts of which sometimes curiously resemble crystalline rocks; this time examining it as far as the Tête Noire.

[2] This conclusion and the reasons are fully stated in a paper (Quart. Journ. Geol. Soc., vol. xlviii, p. 390).

[3] Beiträge, ut supra, pp. 164–8.

[4] Ut supra, p. 395.

[5] On another day we spent a little time at Guttannen.

disappointing. A truly clastic origin was constantly suggested, but was not placed beyond dispute. Shortly afterwards we visited the Museum at Berne, and again examined the famous stems. Pieces had been cut from the ends, probably for the investigation undertaken by Messrs. Von Fellenberg and Schmidt. One passed through the longer stem, affording a crescentic section, and disclosed a third, circular in outline and much smaller. I wrote thus in my diary: "Both 'stems' seem occupied by a material slightly darker, greener, and compacter than the rest of the block. In places there is about 0·1″ or 0·15″ of a phyllite-like substance, where 'bark' should be on the stem. The outer curve of the stem appears not to enter the stone like a fracture would do, but more as a fossil. The bark-like appearance is very conspicuous in the upper, smaller, and 'indented' stem on the face of the block. This, neither in shape, nor in aught else, looks like a 'roll' in the rock. There are two or three surfaces of mechanical division, but they do not appear to be the same, and the glaze on them, which can also be traced in parts of the stem, seems a mere film." After noting one or two other matters, I conclude thus: "If plants, they are very rough and ill preserved; but if the result of mechanical movements, they are of a most extraordinary and exceptional nature, and the rock certainly has the look of an 'arkose' rather than of a true gneiss."

In the memoir before us Messrs. Von Fellenberg & Schmidt give the results of the investigation which was no doubt in process at the last-named date. It is illustrated by seven plates containing nine figures, giving excellent representations of the supposed remains, both as formerly visible and as disclosed by the new sections. The latter are cut from both the upper and lower ends of the longest stem, which, as we can observe in the photograph, has an extraordinary resemblance to a plant. From a cross cut the outline is seen in one case to be an oval, rudely flattened on one side, in a second very rudely crescent-shaped, and in a third nearly circular. The core of the enclosure, a very tough and compact material, blackish green in colour, proves to be an amphibolite; for it is composed almost entirely of short columnar grains of hornblende, between which lie allotriomorphic water-clear felspars, solitary scales of muscovite, zoisite in thread-like clusters, and numerous grains of magnetite with jagged edges. The compact exterior (the supposed bark) is described as practically composed of biotite. Herr Schmidt has also examined the surrounding rock, and maintains the accuracy of his description already published.[1] In regard to the mineral constituents it agrees with what I have seen in specimens believed to come from another part of the block, especially with reference to the rather remarkable changes in texture, though in my specimen the felspar is rather more converted to sericite, and the 'mörtelstructur' is less noteworthy or characteristic than in the slices which he describes. The block is traversed by

[1] Loc. cit., p. 164.

quartz veins and exhibits (as illustrated by a photograph) irregular folds, the crests of which are roughly parallel with the supposed stem, besides other mechanical disturbance. The result of the investigation, into the more minute details of which it is needless to enter, is summed up in the following words: "Der vermeintliche Stamm erscheint als ein Amphibolit-Einschluss, der beim Faltungsprocess gewalzt worden ist": in other words it is not a fossil plant, but a *lusus naturæ*.

The authors, however, leave without notice some interesting questions. We should welcome some explanation of these isolated and singularly shaped portions of hornblendic rock in a mass which elsewhere is generally without that mineral. Are we to regard them as branches of an intrusive vein of dioritic rock, rolled round and perhaps broken up by mechanical movements; or were they originally concretions, somewhat similarly affected, and if so, how are they to be explained? These questions the authors dismiss with the brief remark that such hornblendic inclusions are common in the Guttannen gneiss. That may be so, but I cannot remember to have observed another instance, and in the rock itself hornblende is seldom, if ever, present. In no one of twenty-four slices in my cabinet, three of them, according to report, from the same block as the specimen at Berne, can I find an indubitable grain of hornblende. Again, what explanation must we give of the biotite 'skin,' which so curiously mimics a 'bark.' Was it a contact product of the gneiss and the amphibolite, or a secondary result of their juxtaposition and of mechanical disturbances? Yet more, how do we account for the curious petrographical character of the so-called Carboniferous gneiss, which is so distinctive as to catch the eye at once in the field, and to have led the official geologists of Switzerland to distinguish it from the other gneisses of the region?[1] I am fairly well acquainted with Alpine gneisses, and this one, so far as I can remember, differs from all others known to me. The 'mörtelstructur' also, exhibited by certain specimens from Guttannen, appears to me abnormal. From the majority, which neither resemble true gneisses nor those called mylonitic, it is absent; in the few, where it occurs, the presence of a fragment seems possible.

But I must admit that, though some aspects of the problem seem to have been overlooked by the authors, their petrographical description of this Guttannen gneiss makes it impossible that these structures can be the remains of plants. Hence, whatever the rock may be, they cease to have any special interest. They do not reveal its geological age, and the inferences founded on them are fallacious. That a mistake had been made, I was confident from the first; but of the two possible explanations of it I have apparently adopted the wrong one. Though I naturally regret this, I cannot but rejoice at the effectual laying of another metamorphic spectre, and for that we are deeply indebted to Messrs. Von Fellenberg and Schmidt.

[1] Near Guttannen they term it Seritische Phyllite, an inappropriate name, as I understand Phyllite.

But I may be allowed to remark that their exorcism comes rather late in the day. Such an investigation ought to have been undertaken at least a dozen years ago, that is to say, before the specimen was displayed in the principal museum at Berne, figured and described by a government department, and trumpeted forth to the world by an official geologist as a discovery of prime importance in the history of metamorphic rocks. For twelve years this error has been infecting textbooks and impeding progress; but at last the plant-remains in the gneiss of Guttannen have gone to join the schists, where garnets and staurolites dwell in unity with belemnites, in that limbo which is appointed for exploded hypotheses. *Requiescant in pace!*

IV.—The Geological Age of the Earth.

By J. Joly, M.A., D.Sc., F.R.S.

THE able review of my paper on the Geological Age of the Earth which appears in the March number of this Magazine (p. 124), from the pen of the Rev. O. Fisher, raises again questions of such wide interest that some further remarks, referring principally to the criticism of the distinguished writer of the review, and also to criticisms which I have received from others and which are probably in the minds of many who have considered the matter, may not be out of place.

My position in reference to the mode of estimating the Geological Age of the Earth advocated in my paper has, of course, been that of the Uniformitarian. In answer to general objections on this score, I have only to say that *positive* knowledge on the subject under discussion will probably never be attained by Science. Recognizing this, we may ask of the Physicist on the one hand, and of the Geologist on the other, to what the probable error-limits of their several methods of computation may amount. Will the Geologist admit as probable, denudative activities continued throughout the entire past of geological history which are sufficiently discordant with those of to-day as to bring his error-limit to the magnitude of that confessed to by the Physicist? Will he admit, in short, that the activities of to-day may have been five times excelled or five times diminished, and stand divided between the possibility that they were maintained at the one or the other of these magnitudes throughout geological time? In other words, that our hundred million years may have been five hundred millions or twenty millions so far as denudative processes can tell us? Yet it is just this position the Geologist must assent to before he attains to the uncertainty which divides Physicists on this question at the present day. I need not draw the obvious inference or review the question further.

Among geological methods, that one which I have advocated (and in which I was in part anticipated by Mr. Mellard Reade) claims, as I have contended, the safest and most restricted measure of Uniformitarianism—claims, in fact, uniformity confined more

especially to activities depending on molecular processes; processes in which the mutual presence of the reacting substances is the primary factor, their rate of relative motion or circulation entering the result only in a secondary manner. The method, in short, relies principally on uniformity in the prevalence of that most general of geological conditions, the mutual presence of water and rock material over the land areas. I can best explain by an example. Suppose we desire to estimate the rate of solubility of basalt in water. We arrange that a measured quantity of water circulates over the fragments of rock for a certain time. Now in this experiment, whether we circulate the water quickly or slowly over the rock the result will be the same or nearly the same. This is so because the molecular actions are relatively so slow that even very sluggish circulation of the water suffices to renew the solvent before saturation is nearly attained, and so suffices to preserve the action at its maximum rate. The accelerative influence of friction—as in Daubrée's revolving cylinders—plays relatively but a small part in the work of chemical and solvent denudation on the earth's surface.

But advantages depending on the restriction of our Uniformitarianism are not the only ones which the method claims to possess. The quantities involved, those on which our final answer depends, are more clearly defined and more accurately measurable than those required in Uniformitarian methods based on rates of sedimentation. The total volume of the ocean, its composition, the volume and composition of the river water, are quantities *measurable without speculation*; our knowledge of which will grow with the advance of Science.

The value of this restricted Uniformitarianism may be exemplified in the possibilities involved in the abnormal lunar tides suggested by Professor G. Darwin. If such abnormal tides affected the earth's surface within the period of the Geological Time of which we speak, the mechanical effects would remain the chief record; and we could not say if the wider and barer coasts of the period would contribute more or less than the normal dissolved matter to the ocean. We might argue for more on the ground of increased mechanical action; for less, on the grounds that the soils wherein chemical effects would most favourably progress had not been formed. Very probably the ultimate result would be to affect our numbers but little.

This appropriately leads me to the question of the nature of the primitive ocean. I submit that upon those who wish to imagine the waters of the primeval earth charged with alkaline salts rests the onus of showing how these elements escaped the avidity of the silica under early igneous conditions: the combination of the two being the course of events which we *primâ facie* infer. Or, if they admit such formation of alkaline silicates, they have to explain the subsequent release of the alkali.

On this last point I have in my paper gone on the assumption (justifiable, as I submit) that long-continued attack from free acid cannot be assumed as directed to the one element sodium. Free

acid in the primitive atmosphere must be supposed to act upon the primitive rock much as it would in the laboratory experiment of to-day, when we put such rock to digest in the aqueous solution of the acid. Taking, then, H Cl as probably by far the most abundant of the free active acids of the primeval atmosphere, the outcome of the chemical reaction between the acid and the average rock-crust affords such a mass of sodium as would shorten Geological Time by some six million years. (The corrigenda affixed to my paper should be consulted in reference to this number.)

I may add with regard to vague ideas (not unprevalent) as to long ages of boiling waters acting upon the primitive rocks that calculation relegates these long ages to their proper importance. In fact, the rate of cooling of lava after solidification is so rapid that the long ages shrink to a very few years. "The thickness of the wholly solidified crust grows at first with extreme rapidity—at the end of a year it may be as much as ten metres, with a surface almost or quite cool enough for some kinds of vegetation." (Lord Kelvin, "The Age of the Earth": Address to the Victoria Institute, 1897.) The subsequent rate of cooling may be inferred from a further extract from the same address: "To fix our ideas let us suppose at the end of one year the surface to be 80° (Cent.) warmer than it would be with no underground heat, then at the end of 100 years it would be 8° warmer, and at the end of 10,000 years it would be 0·8 of a degree warmer." So then (and, be it observed, these figures are independent of what we postulate as to the gross thermal actions involved in earth-cooling) the long ages shrink to a period of a century, during which the water fell through its critical point to a liquid resting on our earth, warmed about 8° above what it is to-day; if, indeed, a lesser sun-heat (see Professor Perry's article in *Nature*, vol. lx, p. 247) did not act to make it considerably cooler. Now if we assume that the mean rate of solvent and chemical aqueous denudation during this period was as much as one hundred times as great as to-day, we find 10,000 years' work accomplished in the first 100 years: involving a correction evidently quite negligeable.

But difficulties which may be described as based on highly probable speculation are not the only ones which have to be faced by the advocates of the primitive alkali-charged ocean. Let us suppose they have surmounted the difficulties of accounting for the state of things they desire to establish. They have now to explain how the *known* enormous subsequent formation of sediments was effected from the original rock-crust without putting into the ocean the bulk of the alkalies they have already assumed to be in it. Still more, they have to explain the coincidence that the approximate measure of the sodium missing from these sediments very closely suffices to account (the error being on the side of *excess*) for the amount of sodium in the ocean. This is a point resting on estimates certainly sufficiently reliable for the degree of accuracy required in confirmatory evidence, and can neither be slighted nor ignored till its fallacy is demonstrated.

Before finally dropping the subject of the primitive ocean I must refer to a remark of Mr. Fisher's to the effect—if I understand it aright—that any assumption involving an original ocean free from alkalies also involves chemical proportions between the alumina and the alkalies in the original rocks. "If this proportion did not hold there would have been either alumina uncombined in the crystalline rocks or alkalies over to combine with the acids in the ocean, presumably the latter, seeing that alkali salts abound in it at present. That this due proportion should have existed does not seem probable." I really see no reason why we should look for or except any such equivalence between alumina and alkali. Why not an excess of alumina over alkali? Why not, when a glance at Mr. Clarke's average crust-composition shows that there *is* a very large excess of alumina over what is required to make felspar molecules out of the alkalies or, for that matter, molecules of most of the important alumina-alkali-silicates; and fresh-water lakes of to-day exist among such rocks? Would any special difficulty arise if these lakes were now to be formed by condensation of steam?

Mr. Fisher's criticism on the legitimacy of accepting the river supply of sodium to the ocean is directed to the origin of the chloride of sodium of the rivers; contending that Clarke's crust-percentage of chlorine (0·01) is inadequate to account for the chlorine involved. Hence, he suggests, we must look to Sterry Hunt's "fossil sea-water" contained in sedimentary rocks.

With regard to this point it will conduce to clearness if I first refer to the deductive allowance of sodium chloride required by the presence of this body in rain-water.

In my calculations I had allowed 10 per cent. of the chloride of sodium of rivers as supplied by rain, and on this account not entering the calculations. This, I of course admit, may have been an insufficient allowance. But in the present state of our knowledge on the matter I do not think more or much more is justified. Inland rains show an ever diminishing percentage of salts, and again much of the rainfall richest in salts—that falling immediately on seaboards—finds its way back to the ocean in rills and streams, taking but little from the land. The great rivers of the world, which make up the bulk of the estimate of the river supply to the ocean, gather their constituents from inland areas remote from the coasts. On this point our knowledge will doubtless grow with the years.

It will, however, clear away misapprehension as to the stress to be laid on this matter if I state that, admitting very wide error on my part in making this allowance, the final possible error involved is quite limited in amount. Suppose, in fact, we extend the allowance to a point certainly *not* justifiable, and assume half the total Na Cl of rivers to be derived from rain-water. Then it will be found that the estimate of Geological Time increases from 90 to 100 millions of years. If, then, 10 per cent. is too small and 50 per cent. is too large an allowance, we fix our limits as between 90 and 100 millions of years. If we were *sure* of this we might be well satisfied!

Now as to the "fossil sea-water." In the first place we find very conflicting evidence. Mr. Fisher, himself, quotes two observations—one affording 0·042 per cent. of "chlorine calculated to sodium chloride," the other affording a quantity too small for estimation. Sterry Hunt quotes many analyses of deep-seated springs, some in faulted beds, others in apparently undisturbed beds. The results give the most widely varying amounts of sodium and other elements in solution. Even in the case of wells arising in the same rocks and near together (as in the Trenton Limestone) the relative proportions of dissolved salts vary even to 100 per cent. His results did not lead him to the conclusion reached by Mr. Fisher (that but little sodium had entered the sea since Silurian times), but to the conclusion that the original ocean contained large amounts of calcium chloride, and that alkaline carbonates (derived from decomposing felspars) "which from the earliest times have been flowing into the sea have gradually modified the composition of its waters, separating the lime as carbonate and thus replacing the chloride of lime with chloride of sodium." ("Chemistry of Natural Waters," § 24.) A conclusion essentially in accord with the theory of oceanic supply which I have advocated.

Finally, if we refer to No. 148 Bulletin of U.S. Geological Survey, containing Messrs. Clarke & Hillebrand's valuable collection of rock analyses, we find among many very minute analyses of slates, shales, and clay-slates the chlorine, in one case only, given at as much as 0·01 per cent., and generally left blank or entered as "trace."

But the part played by possible "fossil sea-water" is capable of estimation and of having a true value assigned to its importance.

Let us accept Mr. Fisher's first quoted observation, that most favourable to his suggestion, without reserve. Assume the percentage of chloride of sodium derived from "fossil sea-water" to be 0·042 in all slates and similar rocks, and that such rocks cover one-half the land area of the globe. We will also take the figure of one foot in 6,000 years (which Mr. Fisher favours) as the rate of denudation; and remarking that the sodium chloride supply from this source, in order to be continuous, must keep pace with the rate of denudation, we proceed to estimate the amount of sodium set free by denudation, and express this as a percentage of the quantity of the element contained in the river supply to the ocean. The result, as I reckon, comes out as 0·9 per cent. If, then, this amount of sodium chloride *circulated*, our conclusion as to the duration of Geological Time would be falsified by about this percentage, but the assumptions we made in obtaining even this number are evidently entirely unwarranted.

In point of fact, the conclusion which Mr. Fisher draws from his experiments might indicate that the premises were somewhere at fault—that "not much additional sodium can have accumulated in it (the ocean) since Silurian times." Mr. Fisher elsewhere refers to the setting free of the alkalies of the felspars of granites. What, then, became of all the sodium contributed in this manner to the ocean throughout the ages that have since passed away?

Now contrast the foregoing inadequacy of denudation as acting to set free "fossil sea-water" with denudation as dissolving the alkali-silicates, the latter action being very interestingly brought out by Mr. Fisher himself in his estimate of the rate of denudation required to maintain the river supply of alkalies. I venture to claim that Mr. Fisher has strongly supported my view in showing that $\frac{1}{5000}$ of a foot of granite removed per annum over the land area would suffice to supply the sodium of the rivers. In this connection I again urge that detrital rocks passing more readily into soils and exposing finer material to surface actions probably contribute quite as effectively as eruptive rocks to the supply of alkalies.

Finally, in reference to Mr. Clarke's estimate of the crust constituents, it is worth noting that this estimate is not derived in such a manner as to include extravasated substances. As I gather, it is founded on typical rock analyses. Now chlorine, as it happens, entering only with difficulty into the constitution of silicates, occurs chiefly as an extravasated substance. Hence we find it abundant in mineral springs of volcanic regions and in association with ores. Springs arising in connection with lodes are often heavily charged with chlorides. The sources of supply are in these cases probably deep-seated, and would not enter into estimates of crust constituents based on rock analyses. It will be at once apparent, too, that saline waters, where entering occasionally into deep-seated bedded rocks, may well be derived from such sources; or, again, from inland waters of former times which had never communicated with the ocean. The very various composition of such waters from deep wells supports their non-oceanic origin. For the greater part these sources of chlorine are to be included on the side of the crust constituents and (for a large part) so far as they include sodium in combination, go towards explaining the discrepancy, such as it is, in the equation between the sodium missing from the sediments and the sodium of the ocean.

We have no reason to suppose the contributions from these sources to the rivers to have varied in one or the other direction during the past.

V.—Catalogue of the known Foraminifera from the Chalk and Chalkmarl[1] of the South and South-Eastern Counties of England.

By Prof. T. Rupert Jones, F.R.S., F.G.S.

The sources of information are given below.

D. From T. Rupert Jones's Catalogue of the Foraminifera from the Chalk and Chalkmarl in the Second Edition of Dixon's "Geology and Fossils of Sussex," 1878, pp. 284 and 285.

[1] It is not here practicable to divide the Foraminifera belonging severally to the two formations; but some indication of the distribution is shown by the list at pp. 284 and 285 of Dixon's "Sussex," 2nd edition, 1878. Of the range of these Foraminifera in earlier strata of the Cretaceous series, some particulars may be gathered from the list published in Topley's "Geology of the Weald" (Mem. Geol. Surv., 1875, pp. 423 and 424), as far as known at that time.

Cr. Foraminifera of the Chalk and Chalkmarl referred to in the "Monograph on the Foraminifera of the Crag," by T. Rupert Jones and others: Pal. Soc., parts ii, iii, iv, 1895–96–97.

G. Foraminifera belonging to the Chalk and Chalkmarl referred to in F. Chapman's "Description of the Foraminifera from the Gault": Trans. Roy. Microsc. Soc., 1891–98.

T. Chapman, "On Microzoa from the Phosphatic Chalk of Taplow": Quart. Journ. Geol. Soc., vol. xlviii, 1892, pp. 514–518.

L. Chapman, "Foraminifera of the Phosphatic Chalk of Lewes": Quart. Journ. Geol. Soc., vol. lii, 1896, pp. 470–472.

Jones and Chapman, "On the Fistulose *Polymorphinæ* and the Genus *Ramulina*": Journ. Linn. Soc., Zool., vol. xxvi, 1897, pp. 340, etc. Besides several of the *Polymorphinæ*, this memoir treats especially of *Ramulina aculeata*, Wright, for D, G, T; and *R. globulifera*, Brady, for the column G.

Upper Chalk: Purley, Surrey. Mr. Charles Upton's "Chalk under the Microscope": Proc. Cotswold Nat. Field Club, vol. vii, pt. 2, 1898, pp. 209–216. With the nomenclature revised, the species noticed and figured in this memoir are:—

Textularia globulosa, Ehrenberg.
,, *turris*, D'Orb.
Gaudryina pupoides, D'Orb.
Bulimina Murchisoniana, D'Orb.
,, *ovulum*, D'Orb.
Frondicularia coronata, Perner.
Frondicularia inversa, Reuss.
Cristellaria convergens, Bornem.
Ramulina aculeata, Wright.
,, *globulifera*, Brady.
Globigerina marginata, Reuss.
Rotalia Soldanii, D'Orb.

	D.	Cr.	G.	T.	L.
MILIOLIDÆ.					
Nubecularia tibia, Jones & Parker	...	...	...	*	
,, *Jonesiana*, Chapman	...	...	...	*	
,, *novorossica*, Karrer & Sinzow ...	...	...	...	*	
Spiroloculina limbata, D'Orbigny	...	...	...	*	
Miliolina seminulum (Linné)	...	...	...	...	*
,, *trigonula* (Lamarck)	...	...	...	*	
,, *oblonga* (Montagu)	...	...	...	*	
,, *turgida* (Karrer)	...	...	...	*	
Cornuspira (*Trochammina* ?) *cretacea* (Reuss)	*	*			
LITUOLIDÆ.					
Haplophragmium irregulare (Römer) ...	...	...	...	...	*
,, *ovatum* (Hagenow)	...	...	...	...	*
Lituola neutiloidea, Lamarck	*				
Placopsilina Cenomana, D'Orb.	*				
Haplostiche Sherborniana, Chapman ...	...	...	?		
Bdelloidina aggregata, Carter. From the Chalk; locality not known.					
Webbina rugosa, D'Orbigny.	*				
TEXTULARIIDÆ.					
Textularia globulosa,[1] Ehrenberg	*	*	...	*	*
,, ,, var. *strüsta*,[1] Ehrenberg	...	...	...	*	*
,, *decurrens*,[1] Chapman	...	...	...	*	

[1] These are included in a new genus, '*Guembelina*,' by Dr. Egger, 1899.

	D.	Cr.	G.	T.	L.
Textularia quadrilatera, Schwager... ...	...	...	...	*	
,, *anceps*, Reuss	...	...	...	*	
,, *conica*, D'Orb.	...	*	...	*	
,, *trochus*, D'Orb.	*	...	*	*	*
,, *turris*, D'Orb.	*	...	*		
,, *agglutinans*, D'Orb.	*	*			
,, *concava* (Karrer)...	...	...	...	*	
,, *serrata*, Chapman	...	...	...	*	
,, *sagittula*, Defrance	...	...	...	*	
,, *gibbosa*, D'Orb.	*	*			
,, *Baudouiana*, D'Orb.	*				
,, *prælonga*, Reuss	*				
Verneuilina triquetra (Münster)	*	...	*	*	
,, *Bronnii*, Reuss	*				
,, *spinulosa*, Reuss	...	...	...	*	
,, *pygmæa* (Egger)	*	...	...	*	
Tritaxia pyramidata, Reuss	...	...	...	...	*
,, *foveolata*, Marsson	...	...	...	...	*
,, *tricarinata*, Reuss	...	...	...	*	*
Spiroplecta rosea, Ehrenberg	*				
,, *annectens*, Parker & Jones ...	...	...	...	*	*
,, *biformis*, P. & J.	...	...	...	*	
Gaudryina rugosa, D'Orb.	*	...	...	*	*
,, *Jonesiana*, Wright	...	...	...	*	*
,, *pupoides*, D'Orb.	*	...	*	...	*
Bigenerina pennatula (Batsch)	*				
Heterostomella aculeata (Ehrenberg) ...	*				
Bulimina elegans, D'Orb.	*	*	*	*	
,, *affinis*, D'Orb.	*	...	...	*	*
,, *ovata*, D'Orb.	...	...	...	*	
,, *subsphærica*, Reuss	...	...	...	*	
,, *brevis*, D'Orb.	...	...	*	*	
,, *obtusa*, D'Orb.	*	...	*	*	*
,, *trigona*, Chapman	...	...	...	*	
,, *Murchisoniana*, D'Orb.	*	...	*	*	*
,, *intermedia*, Reuss	*				
,, *obliqua*, D'Orb.	*				
,, *ovulum*, Reuss	*				
,, *Presli*, Reuss	*	...	*		
,, *variabilis*, D'Orb.	*	...	...	*	
,, *polystropha*, Reuss	...	...	...	...	*
Bolivina dilatata, Reuss	...	...	...	*	
,, *strigillata*, Chapman	...	...	...	*	
,, *punctata*, D'Orb.	*	*	...	*	
,, *textularioides*, Reuss	...	...	...	*	
,, *nobilis*, Hantken	...	...	...	*	
,, *obsoleta*, Eley	*				
Virgulina Schreibersiana, Czjzek	*	...	...	*	
,, *subsquamosa*, Egger	...	...	...	*	
,, *Hemprichii* (Ehrenberg) ...	*				
,, *paradoxa* (Ehrenb.)	*				
Pleurostomella subnodosa, Hantken	...	...	...	*	
LAGENIDÆ.					
Lagena sulcata, Walker & Jacob	...	*	...	*	
,, *globosa* (Montagu)	...	*	*	*	
,, *striatopunctata*, Parker & Jones ...	...	...	*	*	
,, *lævis* (Montagu)	...	*			
,, *gracilis*, Williamson	...	*			

	D.	Cr.	G.	T.	L.
Nodosaria Zippei, Reuss, = *raphanus* (Linné)	*	*	*		
,, *radicula* (Linné)	*	...	...	*	
,, *ambigua*, Neugeboren	...	*	...	?	
,, *tenuicosta*, Reuss	...	...	...	*	
Subgenus 1. *Glandulina lævigata*, D'Orb. ...	*				
,, *cylindracea*, Reuss ...	...	...	*		
,, *mutabilis*, Reuss ...	...	...	*		
,, *humilis*, Reuss ...	...	...	*		
Subgenus 2. *Dentalina oligostegia*, Reuss ...	*	...	*		
,, *affinis*, Reuss ...	*				
,, *brevis*, Reuss ...	*				
,, *communis*, D'Orb. ...	*	*	...	*	*
,, *gracilis*, D'Orb. ...	*	...	*	...	*
,, *linearis*, Reuss ...	*				
,, *lineolata*, Reuss ...	*				
,, *Lorneiana*, D'Orb. ...	*	...	*		
,, *monile*, Cornuel ...	*				
,, *sulcata*, D'Orb. ...	*				
,, *sulcata* (Nilsson) ...	*				
,, *obscura*, Reuss ...	...	...	...	*	
,, *consobrina*, D'Orb. ...	...	...	...	*	*
,, *hispida*, D'Orb. ...	...	...	...	*	
,, *obliqua*, D'Orb. ...	...	*			
,, *Roemeri*, Neugeboren	...	...	...	*	
,, *aculeata*, D'Orb. ...	*	...	...	*	
,, *pauperata*, D'Orb. ...	*	*			
,, *nodosa*, D'Orb. ...	...	...	...	*	
,, *expansa*, Reuss ...	...	...	*		
Lingulina carinata, D'Orb.	*	...	...	*	
,, *semiornata*, Reuss	...	...	*		
Rhabdogonium tricarinatum, var. *acutangulum*, Reuss	...	...	...	...	*
Frondicularia Archiaciana, D'Orb. ...	*	...	*	*	
,, *Verneuiliana*, D'Orb.	*				
,, *tricarinata*, D'Orb.	*				
,, *angulosa*, D'Orb.	*	...	...	*	
,, *angusta*, Nilsson	...	...	...	*	
,, *Cordai*, Reuss	*	...	*		
,, *striatula*, Reuss	*				
,, *inversa*, Reuss	...	...	*		
Marginulina glabra, D'Orb.	...	*	...	*	
,, *elongata*, D'Orb.	...	...	...	*	
,, *æquivoca*, Reuss	...	...	...	...	*
,, *compressa*, D'Orb.	*				
,, *ensis*, Reuss	*				
,, *raricosta*, D'Orb.	*				
,, *trilobata*, D'Orb.	*				
Vaginulina lævigata (Römer)	...	*			
,, *costulata* (Römer)	*				
,, *strigillata* (Reuss)	...	...	*		
,, *truncata* (Reuss)	...	...	*		
,, *gaultina*, Berthelin	...	...	*		
,, *comitina*, Berth.	...	...	*		
Cristellaria cultrata (Montfort)	*	*	...	*	*
,, *rotulata*, Lamarck	*	...	...	*	*
,, *gibba*, D'Orb.	...	...	...	...	*
,, *navicula*, D'Orb.	...	...	*	...	*
,, *triangularis*, D'Orb.	*	...	*	*	
,, *gemmata*, Brady	...	...	...	*	

	D.	Cr.	G.	T.	L.
Cristellaria convergens, Bornemann ...	...	...	...	*	
,, *Gaudryana*, D'Orb.	...	...	...	*	
,, *gaultina*, Berthelin	...	...	...	...	*
,, *acutauricularis* (Fichter & Moll)	...	...	...	...	*
,, *obsoleta*, Jones	*				
,, *ovalis*, Reuss	*				
,, *recta*, D'Orb.	*				
Flabellina rugosa, D'Orb.	*	...	...	*	
,, *Baudouiana*, D'Orb.	*	...	...	*	
,, *pulchra*, D'Orb.	*				
,, *ornata*, Reuss	*	...	...	*	
,, *cordata*, Reuss	*				
,, *elliptica*, Nilsson	*	*			
,, *ovata*, Geinitz	*				
Polymorphina gibba, D'Orb.	...	...	...	*	
,, *acuminata*, D'Orb.	*	...	...	*	
,, *Thouini*, D'Orb.	*				
,, *sororia*, Reuss	...	*	*	*	
,, *fusiformis* (Römer)	...	...	...	...	*
,, *compressa*, D'Orb.	...	*	*		
,, *communis*, D'Orb.	...	...	*		
Uvigerina Canariensis, D'Orb.	...	...	...	*	
Sagrina rugosa, D'Orb.	*	...	...	*	
GLOBIGERINIDÆ.					
Globigerina bulloides, D'Orb.	*	*	*	*	*
,, *cretacea*, D'Orb.	*	...	*	*	*
,, *marginata*, Reuss	*	...	...	*	*
,, *æquilateralis*, Brady	...	...	*	*	*
,, *Linnæana*, D'Orb.	...	*			
,, *elevata*, D'Orb.	*				
,, *pelagica*, D'Orb.	*				
ROTALIIDÆ.					
Planorbulina Clementiana, D'Orb.	*	...	...	*	
,, *Lorneiana*, D'Orb.	*	...	...	*	
,, *Voltziana*, D'Orb.	*				
Truncatulina lobatula (Walker & Jacob) ...	*	...	...	*	
,, *variabilis*, D'Orb.	...	*	...	*	
,, *Ungeriana* (D'Orb.)	*	*			
,, *Haidingeri* (D'Orb.)	*				
Discorbina Berthelotiana (D'Orb.)	...	...	...	...	*
Anomalina ammonoides (Reuss)	*	...	*	*	*
,, *ariminensis* (D'Orb.)	*	...	...	*	
,, *grosserugosa* (Gümbel)	...	...	...	*	
,, *rotula* (D'Orb.)	...	...	...	*	
Pulvinulina elegans (D'Orb.)	...	*	...	*	*
,, *Karsteni* (Reuss)	...	*	...	*	
,, *punctulata* (D'Orb.)	...	...	...	*	
,, *Menardii* (D'Orb.)	*	*	...	*	
,, *Corderiana* (D'Orb.)	*				
,, *crassa* (D'Orb.)	*				
,, *Micheliniana* (D'Orb.)	*				
Rotalia exsculpta, Reuss	...	...	...	*	
,, *Soldanii*, D'Orb.	...	...	...	*	*
,, *Beccarii* (Linné)	...	*	...	*	
Calcarina Spengleri (Gmelin)	*				
Gypsina ovata, Marsson	...	...	...	...	*

REVIEWS.

I.—A Memoir on the Palæozoic Reticulate Sponges constituting the Family Dictyospongidæ. By James Hall, State Geologist and Palæontologist, in collaboration with John M. Clarke, Assistant State Geologist and Palæontologist. Imp. 4to; pp. 350, plates lxx and 45 figures in the text. (University of the State of New York, 1898.)

THIS elaborate monograph treats of a family of siliceous sponges which occur very abundantly in certain portions of the Chemung division of the Upper Devonian in the State of New York; they are also present in lesser numbers in the sub-Carboniferous rocks of Ohio and Indiana. Beyond the bounds of the United States they are represented by a few forms in the Psammites du Condroz (on the same horizon as the Chemung) in the North of France, which have been described by Dr. Charles Barrois; one species is also known from the Middle Devonian of the Eifel, and another, which appears to be the oldest representative of the family, has been found in the micaceous shales of the Upper Ludlow of Westmorland, and described by McCoy under the name of *Tetragonis Danbyi*.

The sponges of this family are very varied in shape, but the majority are vasiform, cylindrical, or prismatic, whilst others are flattened saucer-shaped, and not infrequently they are of large size. They consist of a thin wall which is built up of fascicles, principally of elongate rod-like spicules intermingled with others of cruciform, five and probably six rays, arranged in vertical and horizontal bands so as to form a lattice-like mesh with rectangular interspaces. With the exception of a few specimens from the sub-Carboniferous rocks of Indiana, these sponges are only known in the form of casts or solid moulds of the interior hollow of the sponge, which has been infilled with the arenaceous or calcareous materials of the rock in which they are imbedded. These moulds retain, very perfectly as a rule, the form of the sponge scarcely at all compressed, and their outer surfaces show, in a fairly definite manner, the impressions of the spicular bands bounding the angular mesh-interspaces. But it is very difficult to determine from the impressions the form, size, and disposition of the individual spicules composing these bands, and hence arises the principal obstacle in the classification of these sponges, which rests to a considerable extent on their outer form and proportions, characters of very subordinate value if we may judge from the existing members of the class.

In some specimens from the sub-Carboniferous rocks of Indiana where the matrix is a calcareous shale or mud, the originally siliceous spicules of the bands are now replaced by pyrites, and it has been possible to determine their forms to a certain extent, but of still greater significance is the discovery in these pyritized specimens of very minute flesh-spicules comparable with those in existing Hexactinellids. Amongst these may be mentioned small regular six-rayed forms with the rays minutely spined, peculiar modifications

of the pinule, and a comparatively new form, termed an umbel, consisting of a plump rod with an umbrella-shaped summit. There are also rods with anchor-shaped terminations as in recent sponges of the same group.

The Dictyospongidæ in the Chemung rocks of New York are not infrequently met with associated together in large numbers in particular beds of a somewhat coarse sandstone, in which they lived and flourished in large colonies. This habitat is in striking contrast to that of recent hexactinellid sponges, of which the greater number live in mud or ooze and often at considerable depths, whereas the sandy matrix on the surface of which their Devonian progenitors lived indicates a comparatively shallow sea.

The Bibliography of the Dictyospongidæ is not without interest. The earliest known example, *Hydnoceras tuberosum*, was thus named by Conrad, in 1842, under the supposition that it was an unusual form of Cephalopod, and in the same year Vanuxem described *Uphantænia Chemungensis*, another member of the family, as a marine plant. In 1863 James Hall, the senior author of the present monograph, proposed a new genus, *Dictyophyton*, with nine species, including *Hydnoceras tuberosum*, Conrad, the generic name signifying that in Hall's opinion the fossils belonged to marine Algæ. That these supposed fossil plants were in reality siliceous sponges related to the recent Euplectellidæ, was clearly shown by R. P. Whitfield in 1881, who pointed out that in this case the generic term *Dictyophyton*, Hall, was a misnomer, and that therefore it would be necessary to go back to one of the earlier names, *Hydnoceras*, Conrad, or *Uphantænia*, Vanuxem. In 1884 Professor Hall defined several new genera, but though the spongoid character of the family is fully recognized in the name given to it, the term *Dictyophyton* is retained, and the same course is followed in 1890, when other new species were placed in the genus. In the meantime a large collection of these fossils had been gathered together by Professor Hall, who handed them over to Dr. J. M. Clarke for revision, and it may therefore be fairly assumed that this latter author is mainly responsible for the classification and descriptions in the present monograph. We find in it a veritable revolution as regards the nomenclature: the name *Dictyophyton*, Hall, is entirely given up, since it "has proved a misleading term among the sponges"; Conrad's genus *Hydnoceras*, which Hall had merged in *Dictyophyton*, is again revived, and the various species placed under *Dictyophyton* by Hall, and by others who had adopted the generic name without reference to its original signification, are now distributed among *Hydnoceras* and ten new genera!

A summary of the monograph shows that the Dictyospongidæ family is divided into 7 subfamilies, all new; 32 genera, 20 of which are new; and 128 species, of which 77 are new. The descriptions of genera and species are drawn up very carefully, but, as already remarked, the structural characters of the skeleton in these sponges are very imperfectly shown in their casts, and differences of mere outer form and mode of growth, on which many

of the generic and specific features are mainly based, are too inconstant to be relied on.

The varied forms of these sponges are very clearly shown in the admirable plates, whilst figures of the remarkable flesh-spicules are given in the text.

This monograph is a worthy addition to the series of volumes on the Palæontology of the State of New York which, under the authorship of the late Professor James Hall, have appeared during the last fifty years, and it also furnishes a happy augury for the further continuance of the series by his successor, Dr. J. M. Clarke.

G. J. H.

II.—Text-Book of Palæontology. By Karl A. von Zittel. Translated and edited by Charles R. Eastman, Ph.D. Revised and enlarged. Vol. I. pp. viii and 706, with 1,476 woodcuts. (London: Macmillan & Co., 1900.)

OF recent years it has become more and more evident that it is impossible for one man, however great, to write unaided an advanced text-book dealing with all the branches of one science. The only way in which an advanced text-book can be compiled so as to be of real value is by the co-operation of a number of specialists under the direction of a competent editor. This has already been done in some sciences, and to this class of work we may refer the book under consideration, which marks an epoch in palæontological literature.

We had long envied our German colleagues the possession of Zittel's *Handbuch der Palaeontologie*, for although it was for the use of all palæontologists, still a work in a foreign language is never quite the same as one in our own; but now we feel that we have the advantage over them, for in the present work we have the foundation laid by Zittel with a superstructure by a number of zoologists who, as specialists in the groups with which they are dealing, possess worldwide reputations. We have only to glance at the list of collaborators to see what an immense advance this work makes on all other palæontological text-books.

The only disadvantage which this type of work appears to us to suffer from, is the fact that specialists are, after all, but human beings, and consequently apt, in dealing with their favourite group of animals, to give undue prominence to their own views, especially in matters of classification and nomenclature; consequently the advanced student will do well to bear in mind that each chapter is either written or revised by an ardent enthusiast, and not by a cool and perhaps unprejudiced general palæontologist.

Looking at this work in more detail, we find that while the chapters on the *Protozoa* and *Cœlenterata* stand essentially as in the original, those on the *Molluscoidea*, *Mollusca*, and *Trilobita* are entirely rewritten, and the remainder enlarged and revised. We cannot help regretting that some of the short descriptions of the sub-kingdoms were not revised along with the other matter, since

such statements like those on p. 257 *re* the supposed relationships of the Molluscoidea to the Mollusca, and the supposed total absence of all hard parts in Tunicata, are apt to mislead the student, unless he has had a very thorough zoological training. So also would some of the definitions of the classes and orders of the Mollusca.

Studying a work of this description one cannot help wondering whether specialists in different groups will ever come to any agreement as to the differences which constitute species, genera, and families, and in this connection we think that the student who voluntarily takes up the study of the fossil Cephalopoda will be a bold man indeed.

We must congratulate Dr. Eastman and his collaborators on the excellent results which have attended their efforts, and we think that Professor von Zittel was wise in allowing his work to be expanded and altered to its present form, which Messrs. Macmillan have put before us in such excellent condition. All English-speaking students of Palæontology will rejoice at its appearance.

III.—A Treatise on Zoology. Edited by E. Ray Lankester. Part III: The Echinoderma. By F. A. Bather, M.A., assisted by J. W. Gregory, D.Sc., and E. S. Goodrich, M.A. pp. vi and 344, with 308 figures in the text. (London: Adam & Charles Black, 1900.)

AT last we have actually before us the first instalment of Professor Lankester's long promised Treatise on Zoology. It is somewhat unfortunate that the appearance of this part has been so long delayed (for we notice that the MS. of some parts of the work were completed rather more than three years ago), since, as we all know, zoological text-books have a way of getting out of date very rapidly, owing to the enormous amount of work which is being done all over the world.

Professor Lankester promises us nine more parts of this work, which are to be written as far as possible by graduates of Oxford University. We only hope that these parts will make a fairly early appearance, since, judging from the present part, they should be of immense service both to the palæontologist and to the student of living forms.

The present work deals with the Echinoderma, and since the greater part of it is written by two palæontologists it will probably appeal more strongly to the readers of this Magazine than some of the parts which have yet to appear. The ordinary zoologists will be apt to consider that the palæontological side is perhaps a little overdone; but when we remember that the phylum Echinoderma includes the Pelmatozoa, three classes of which are extinct, and the remaining class, the Crinoidea, consists mainly of fossil forms, the preponderance of the palæontological aspect becomes at once accounted for. This group occupies 179 pages and is the main

feature of the book; coming as it does from the pen of Mr. F. A. Bather, who has made such a special study of the group, it will form a classical work of reference for all students of the Pelmatozoa, and will form an interesting companion to the shorter account of this group revised by Mr. Wachsmuth in Zittel's Text-book. We think, however, that Mr. Bather might have dealt a little more fully with the actual facts of anatomy in the general part (pp. 1–37), and given us a few more figures of the general morphology of the Echinoderma, and perhaps fewer theoretical diagrams.

The Holothurians are very briefly dealt with in 18 pages, and somewhat meagrely illustrated with a series of almost blackboard diagrams. The remaining 96 pages are devoted to the Stelleroidea and the Echinoidea, and are from the pen of Dr. Gregory. Both these accounts seem unduly compressed, and the forms are perhaps dealt with too much from the standpoint of the skeleton, as if the variations in the soft parts were comparatively of little value.

The whole work is profusely illustrated with a large number of excellent figures, most of which are new. Some, however, of those not acknowledged in the description are old ones, and one or two of the old ones might well have been replaced by fresh figures, notably fig. iv, p. 242, which is a very poor representation of the general anatomy of a starfish.

Professor Lankester, in his conception of this work, has filled a void long felt in zoological literature, and, in obtaining Mr. Bather's assistance to write the greater part of the Echinoderma, he has exercised a wise selection, the result being that the student is furnished with a most admirable systematic text-book, in which he will find the characters of the classes, orders, families, etc., of the Echinoderma dealt with in a manner not hitherto attempted in any of our zoological text-books. We can only hope that the succeeding parts will be of equal merit and not too tardy in their appearance.

IV.—Memoirs of the Geological Survey: The Geology of Belford, Holy Island, and the Farne Islands, Northumberland. By William Gunn, F.G.S. 8vo; pp. iv, 155. (London: Eyre & Spottiswoode, 1900. Price 2*s.* 6*d.*)

THIS Memoir is an Explanation of the New Series Geological Survey Map, Sheet 4 (Old Series 110 S.E.), and it contains accounts of the Carboniferous Limestone Series, Glacial Drifts, and more recent deposits, with descriptions also of the Whin Sill, whose northern limit is seen in the Farne Islands. The chief part of the Memoir is occupied with descriptions of the Carboniferous rocks, the Tuedian or Cement-stone group, the Fell Sandstone, the Scremerston Coal, and the Limestone groups, the two latter containing seams of workable coal. Details of many pit-sections are given, and there are lists of Carboniferous fossils.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—February 21st, 1900.—J. J. H. Teall, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:—

1. "The Bunter Pebble-Beds of the Midlands and the Source of their Materials." By Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

The author states the results of occasional work in the Bunter Conglomerate of Staffordshire. After a sketch of matter already published, he gives additional particulars of the lithology of the pebbles, more especially of the felstones and of some rather compact dark rocks. Of the former he has now obtained about thirty varieties: orthoclase-felsites and porphyrites, some with, others without quartz; several contain tourmaline, which sometimes has replaced biotite, sometimes felspar. One pebble exhibiting reddish spherulites in a dark matrix, once doubtless glassy, but now devitrified, is not like any British rock known to the author. Of the dark pebbles, some are fine-grained quartzites blackened with opacite; others, varieties of 'schorl-rock'; and two (which Dr. G. J. Hinde has kindly examined) are radiolarian cherts, which, however, cannot be more precisely identified.

The mode of transport and source of the pebbles are next considered. The reasons, already published, for a fluviatile, as opposed to a marine, origin are briefly summarized. If the former be accepted, certain conditions must be satisfied, which bear directly on the position of the source. These beds represent the destruction of large masses of rock. If brought by rivers, those must have been important and powerful, of a continental rather than an insular type. Hence the necessary physical conditions exclude limited districts near the Midlands, such as the Wrekin, Lickey, Hartshill, and Charnwood, even if they included (which is not the case) the right types of rock. As regards the Longmynds, their argillites, if they occur, are not common; their conglomerates do not exactly resemble the Bunter pebble-beds; their 'Torridonian' is a quartz-rhyolite rather than a quartz-felspar grit. The rocks required cannot be supplied from either Wales, the Lake District, or the Pennine range, and we have no reason to suppose them concealed under Eastern and South-Eastern England. We have therefore to choose between a southern and a northern source. Cornwall and Devon might perhaps furnish the schorl-rocks; possibly also one or two varieties of felstone (though this is doubtful) and the right quartzites and quartz-felspar grits occur in the Budleigh Salterton pebble-bed. But the characteristic flat ellipsoidal pebbles of grit, dominant here, are not found in the Midlands. Physical conditions also seem opposed to a northward flow of the rivers of Britain in the earlier part of the Trias. In Scotland, however, we find the right varieties of quartzite, the Torridonian

grit, and many felstones, some apparently identical with, others closely related to, those in the Midlands. The rarity of tourmaline rocks in that region is the only difficulty in looking to it or its vicinity for the main source of these pebbles.

2. "Further Evidence of the Skeleton of *Eurycarpus Oweni*." By Professor H. G. Seeley, F.R.S., F.L.S., V.P.G.S.

The original specimen from which this species was named was obtained from the Sneewberg (South Africa) in 1876, and after being doubtfully referred to *Dicynodon* was described and figured in 1889. It was presented to the British Museum by Mr. Thomas Bain through Sir Henry Barkly. The skull was found with the complete specimen, and a short memorandum of its characters, with a sketch of the skeleton, including the skull, was made by Mr. T. Bain and has been preserved in the British Museum. Half of the counterpart of the slab was presented to the author by the Rev. C. Murray, and by means of it complete casts of part of the skeleton have been obtained.

From Mr. Bain's sketch the author is able to give some account of the skull, including its dimensions. From the material mentioned above, he gives new facts with regard to the vertebral column, the ribs, the shoulder-girdle, the fore-limb, the hind-limb, and the armour, which was present upon the limbs and the fore-part of the body.

The locality from which the animal was obtained had already yielded to Mr. A. G. Bain *Lycosaurus pardialis, Tigrisuchus simus, Cynosuchus suppostus, Scalaposaurus constrictus*, and *Dicynodon leoniceps*. It would therefore appear to be one of the chief localities for the Lycosaurian types of Theriodontia and to be on the horizon of the *Dicynodon*-beds. The recovery of the missing half of the Murray slab, with the evidence of the skull and pelvis which it would give, is to be desired in completion of our knowledge of this fossil animal.

II.—March 7, 1900.—J. J. H. Teall, Esq., M.A., F.R.S., President, in the Chair. The following communications were read:—

1. "Notes on the Geology of Gilgit." By Lieut.-Gen. C. A. McMahon, F.R.S., F.G.S.

This paper is based on observations in the field made by Capt. A. H. McMahon, C.S.I., C.I.E., F.G.S., and Capt. J. R. Roberts, I.M.S., and on the petrological examination of the specimens sent home by them. It is divided into three parts. Part I refers to the work of previous observers, and embodies a brief petrological description of the four granites and aplite intrusive in the sedimentary rocks of Gilgit. Part II consists of a topographical account of the Gilgit rocks from Askole and Nanga Parbat on the south to the northern passes leading into the Russian Pamirs. Part III recites the author's conclusions from the facts recorded in the paper. Briefly stated, they are as follows:—

That at one period in the elevation of the Hindu Kush the strata were thrown into a series of folds and compressed into a series of uniclinal beds with a vertical dip.

That the direction of the main drainage of the area was determined

before, or at the commencement of, the last series of earth-movements that crumpled up the strata.

The sedimentary rocks were profusely invaded by granite and diorite, and profoundly metamorphosed by contact-action.

As regards the age of the rocks, the author gives his reasons for identifying the Gilgit limestones with the conformable Carbo-Triassic series of the Himalaya. This series was mapped by Mr. R. Lydekker, F.R.S., in the neighbouring district of Kashmir, and it has been traced up to the border of Gilgit. Sir Martin Conway's specimens, reported on by Professor Bonney and Miss Raisin, enable the author to connect it with the limestones of Gilgit. From this correlation the author concludes that the oldest rock in the Gilgit area is of Silurian or Lower Carboniferous age, and that the most recent are of Triassic or even later age. As all the granites are intrusive in the most recent beds, it follows that the granites are younger than the Trias. The author gives his reasons for believing that the oldest granite was erupted while the crumpling of the Gilgit rocks was in progress; but that a portion, at all events, of the younger granites was erupted after the crumpling had taken place.

The author offers an hypothesis to explain certain structures found in the Gilgit granites, including the granophyric structure so common in them.

All the Gilgit granites, the author believes, came from the same igneous reservoir, the differences in them being due to gradual and progressive silification caused by the gradual crystallizing out of the comparatively basic minerals; the process extending over a long period of time measured in years.

2. "The Rocks of the South-Eastern Coast of Jersey." By John Parkinson, Esq., F.G.S.

In this paper the author has continued the study of the deep-seated rocks of Jersey begun in a communication presented to the Society last session entitled "On an Intrusion of Granite into Diabase at Sorel Point (Northern Jersey)." A great resemblance exists between these rocks in the north and south of the island, and it is concluded that they represent parts of the same magma; but in the south-east additional complications arise, owing to the intrusion of another rock before the invasion of the granite. For convenience of study the district under discussion is divided into two parts, an eastern and a western, separated the one from the other by the western termination of the Grève d'Azette. In the eastern district the granite and the intrusive rock which preceded it are found; in the western a rather different rock invades the diabase. The latter is correlated with the aplite intrusion of the northern coast.

Taking first the earlier intrusion found at Le Nez Point, it is shown that it consists of a rock more acid than a diorite, but on the whole more basic than the granite which followed it. Microscopical examination indicates that it was poor in ferro-magnesian minerals, and that quartz and orthoclase, though present, are not found in the proportion which characterizes the granite. This rock, the exact composition of which it is not easy to discover, has

invaded the diabase, as well as a dioritic rock associated with it, streaking and veining them. Mixing took place as a result of such intrusion, producing a composite rock characterized by elongated hornblendes which occasionally attain a considerable size. Mica is conspicuously absent.

The intrusion of the granite following this is next described. Here, as on the northern coast, local absorption of the older rock has taken place. The resemblance between the mixed rocks is commented upon, and a parallel drawn between the basic and acid rocks of Jersey and the eastern and northern coasts of Guernsey.

Passing to the western district, the aplite of St. Elizabeth's Castle is described, together with the melting and absorption which have taken place as a consequence of this intrusion. Field evidence indicates that this is later than any intrusion found in the eastern district, though the difference in age is probably but slight; thus it bears out the results of work on the northern coast, where the intrusion of an aplite was found to have followed that of a porphyritic granite. Reasons are given in the body of the paper for believing that successive intrusions cannot be separated the one from the other by hard-and-fast lines. Finally, it is suggested that the various rocks considered are closely related, and indeed form parts of one magma, the successive injections of which became progressively more acid.

3. "The Rocks of La Saline (Northern Jersey)." By John Parkinson, Esq., F.G.S.

The rocks of La Saline closely resemble those of Sorel Point, about a mile to the west. A coarse porphyritic granite is found in the upper part of the cliff which passes rapidly into an equally coarse but redder rock, approaching an aplite in composition. The latter occasionally contains mica in some quantity, and evidence is given for concluding that this mineral has been produced by the combination of the constituents of the augite of a dolerite, through which the acid magma forced its way, and the felspathic parts of the magma itself. This evidence is based (i) on the fact that in one part of the Bay a few outcrops of rock are found identical with others from Sorel Point, which have been clearly formed by the absorption of fragments of diabase (dolerite) by an acid magma; (ii) on the presence of fragment-like patches rich in mica in the aplite itself; (iii) by the irregular distribution of this mineral through the acid rock. A peculiar quartz-less rock is next described containing large orthoclases, plagioclase, and chlorite: it is concluded that the last-named mineral is derived from mica. With some hesitation the structure of this rock is explained by supposing that the intruding magma melted a mass of dolerite, completely dissolved the felspar, and produced mica in the manner indicated above; and that as freedom of movement was not greatly restricted, segregation of the basic elements followed, enclosing among them numerous porphyritic orthoclases. Some movement of the whole then appears to have taken place.

CORRESPONDENCE.

PTEROCONUS MIRUS, HINDE.

SIR,—Last Spring Mr. Upfield Green allowed me to see the fossils to which he afterwards gave the name *Nereitopsis Cornubicus* in the Trans. Roy. Geol. Soc. Cornwall, vol. xii, p. 227, regarding them as Annelids. While studying them, point after point came out which forced me to the conclusion that they belonged either to *Orthoceras* or to a closely allied genus. The surface ornament, the contour, the septa, and other details seemed thus, and only thus, explicable. The chief perplexity was that, while the other parts were crushed and partially obliterated, the siphuncle remained rigid; but the consideration of *Actinoceras*, and still more *Huronia*, seemed almost to clear this away, and I felt able to tell Mr. Green that they were in my opinion certainly Cephalopoda.

With these fossils, or some of them, Dr. Hinde identifies those collected by Mr. Howard Fox at Bedruthan, to which he has given the name *Pteroconus mirus* on p. 149 of the present volume of the GEOLOGICAL MAGAZINE, regarding them as Hyolithidæ. These fossils he has very kindly shown to me, and with the identity of three of the specimens (his figs. 2, 3, 4) I agree, though still venturing, in spite of such weighty authorities as Dr. Hinde and Mr. Crick, to believe that I see in them Cephalopoda. The fossil represented by his fig. 1, I confess that in my hurried examination of it I could not fully decipher; nor did I feel quite certain that it was the same as the rest; but at the same time some Devonian Orthocerata which I have seen did appear as if they might go some way toward explaining it.

Fossils in such an extremely obscure state of preservation may, I think, allow of a different interpretation without disrespect to the authority of my valued friends; and, indeed, I think that my difference of view is mainly due to my regarding them as masked and distorted by the processes of fossilization to a very much greater extent than they appear to consider. G. F. WHIDBORNE.

FOSSILS IN DEVONIAN ROCKS OF NORTH CORNWALL.

SIR,—The fossils figured by Mr. Green in the Transactions of the Geological Society of Cornwall under the name of *Nereitopsis Cornubicus* being very interesting ones, their further illustration and description in the more widely circulating GEOLOGICAL MAGAZINE is a matter of congratulation. But is the renaming of them quite in accordance with accepted rules of nomenclature? Dr. Hinde in his paper[1] mentions the fact that Mr. Green did not fully describe it; but many accepted names rest on figures alone. He also states that as, in his opinion, the fossils could not "in any way resemble any species of *Nereis*," the name is "misleading and should be changed." But has not the author of a genus the right to express in the name what the form reminds him of, even if the resemblance be fanciful?—e.g. *Ophiopsis*, *Pileopsis*, *Galeopsis*. And would not the new name proposed (*Pteroconus*) be open to the same objection,

[1] GEOL. MAG., Dec. IV, Vol. VII, p. 149.

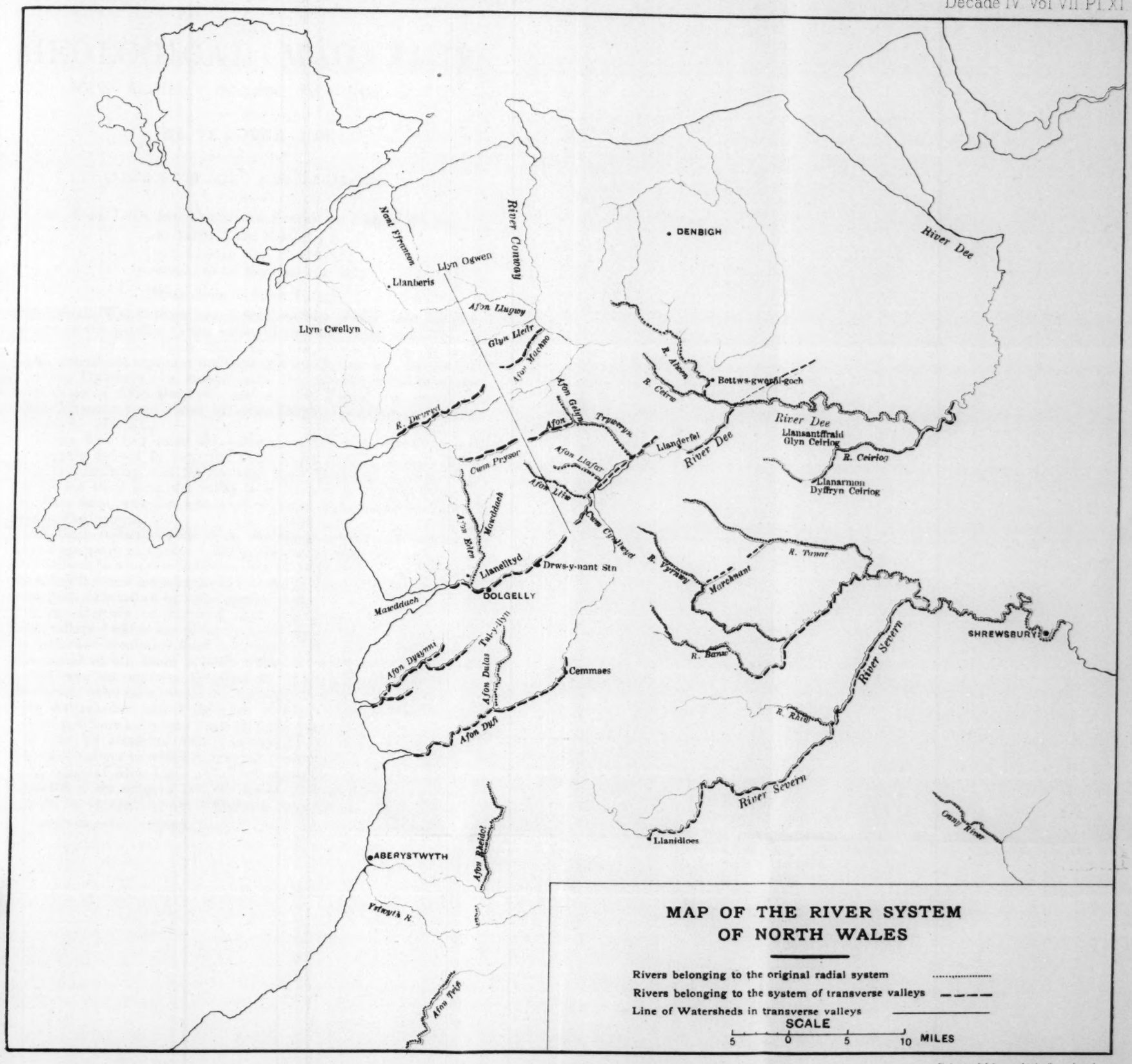
the first half comparing the "flap- or fin-like extensions" to a *wing*, which is not a serial organ, and the second half suggesting a relationship to a genus of shells? As to the specific name, Mr. Green gave the name *Cornubicus* to his specimens as a group, regarding them as specifically one; but if they are to be divided, then his statement that a certain specimen "differs from the others" indicates that the "others" are regarded as the type. As Dr. Hinde says he is "undecided" whether his specimens are different from these others, it follows that the statement *sp. nov.* after the name he gives is quite unproved. I would also point out, what cannot have struck Dr. Hinde, that the name *mirus* implies that the specimens so named are the first discovered. One is not astonished at further examples of a known form, however wonderful, turning up, and Mr. Green showed his specimens to his friends, Cornish and others, and recognized examples in the Penzance Museum before the beginning of last year, when Mr. Fox's specimens were found. In justice, therefore, to Mr. Green the new name ought to be relegated *in toto* to the synonymy.

As to the nature of the organisms represented, there will probably continue to be a difference of opinion. The use of the word 'shell' in Dr. Hinde's description is an assumption, as it is admitted that nothing now remains but "some compound of iron," which may be derived, as in the case of the chalk Ventriculites, from other things than shells. The irregularity of the outline indicates rather a soft-bodied animal. The downward bend of the flaps in one specimen, their upward bend in another, and the straight direction of their bases in a third indicate that they were flexible. Dr. Hinde seems to think that downward-bending flaps on both sides might appear as upward-bending if the fossil were turned round on its median axis, but this is impossible. He also states that we cannot tell whether the dorsal and ventral sides are alike or not; but as in one specimen each later flap "dips slightly *under*" the next preceding, we can tell that we are looking at the opposite side in any other specimen if, as appears to be the case in his second figure, the later flap lies slightly *over* the next preceding. The supposed rod may very well be the remains of the intestine filled with matrix, or mere folds in the shrunken integument. In Mr. Green's specimens the bases of the flaps are somewhat swollen, and the distal lines are slightly radial rather than absolutely parallel.

If, then, we figure a soft-bodied animal, lineally elongated, with a series of flexible organs on each side consisting of oblique flaps ending distally in slightly radiating prolongations, the description fits so well with that of a polychætal annelid, as exhibited by many larvæ and by the adult of *Aphrodite*, and so ill with that of any other known group of organisms, that this interpretation of the fossils seems the most reasonable, especially as we have reason to believe that this group was well established before the Devonian period.

J. F. Blake.

Erratum.—On p. 147, line 19, *for* "adunate" *read* "inadunate."



Edwin Wilson, lith. Cambridge.